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COMPARISON OF TYPES OF FIREPROOF CONSTRUCTION

By

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and

ANALYSIS OF COST OF TYPES OF FIREPROOF CONSTRUCTION

By

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Comparison of Types of Fireproof Construction

By Chester L. Post,* M. W. S. E.

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Every building presents numerous problems to its designer, each requiring careful analysis to select the best type of construction for that particular piece of work. Fireproofing is probably the most important of these. The author of this paper was requested to prepare a general comparison of the better known types of fireproof construction recognizing the fact that no universal rules could be laid down and that the conclusions could not be expected to apply to all conditions. It is hoped that the comparisons contained herein will be a general guide for designers in analyzing the requirements for structures.

Cost of construction is not the full measure of economy. The adaptability of any type of construction to a particular problem is as much a measure of economy as the first cost.

Maintenance costs must also be considered in determining the question of economy.

As the next paper takes up the matter of detailed costs, this paper will be confined to a description of the more important and common types and a discussion of their advantages, disadvantages, adaptability and relative costs.

The following brief discussion of fireproofing materials will be of advantage in considering fireproof construction.

The following table is taken from Table of Fire Resistance Periods in Report of Fire Tests of Building Columns These tests were jointly conducted at Underwriters' Laboratories at Chicago, Illinois, by

Associated Factory Mutual Fire Insurance Companies,

The National Board of Fire Underwriters and the

Bureau of Standards, Department of Commerce.

It will be observed that with the exception of the concrete with aggregate consisting of silicious gravel, the concrete protection was much more effective than any of the other methods of fireproofing. The items selected are only a few of those given in the report but fairly represent the relative values of the

FIREPROOF MATERIALS

Fireproofing Material	Description	Thickness in Inches	Protection in Hours
1. Concrete	Limestone or Calcareous Gravel Aggregate	2"	4
2. Concrete	Trap Rock Aggregate	2"	3
3. Concrete	Granite, Sandstone or Hard Coal Cinders Aggregate	2"	2½
4. Concrete	Silicious Gravel Aggregate.....	2"	1
5. Plaster	2 Layers Portland Cement Plaster on Metal Lath with Hydrated Lime and Sand.......	2 at ⅞"	1½
6. Gypsum		2"	1½
7. Hollow Clay Tile		2-3-4"	1
8. Brick	Chicago Common Brick on Edge	2¼"	1

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different materials. No tests were made in which blast furnace slag was used as aggregate. It is generally assumed that slag concrete has a very high resistance to fire.

Contrary to the popular belief, limestone aggregate proved better for fireproofing than trap rock or granite.

Chicago Building Ordinance Fireproofing Requirements

Fireproofing qualities of different materials are reflected by the Chicago Building Ordinance which states that "the materials which shall be considered as filling the conditions of fireproof covering are: (1) Burnt Brick, (2) Tiles of Burnt Clay, (3) Approved Cement Concrete, (4) Terra Cotta."

Their relative value is indicated by the thicknesses required for structural steel columns as follows:

"Interior Columns. (a) Covering of interior columns shall consist of one or more of the fireproof materials herein described. (b) If such covering is of brick it shall be not less than 4" thick; if of concrete not less than 3" thick; if of burnt clay tile such covering shall be in two consecutive layers, each not less than 2" thick, each having one air space of not less than ½", and in no such burnt clay tile shall the burnt clay be less than ⅝" thick; or if of porous clay solid tiles, it shall consist of at least two consecutive layers, each not less than 2" thick; * * *"

Concrete covering is to be three inches, while the other coverings require a thickness of four or more inches. Another advantage is gained by the use of concrete for structural steel column fireproofing, as the unit stresses in the structural steel can be increased by approximately 2000 lb. per square inch.

The following discussion will be based on the requirements of the Chicago Building Ordinance:

Foundations

Foundations do not have very much bearing on the subject under discussion, as the type of foundation to be used is usually fixed by the weight of the structure, the underlying soil conditions and the adjacent present and future buildings.

Foundations are of three general types: (1) Spread Foundation; (2) Pile Foundation, and (3) Cylindrical Pier extending down to hard pan or rock.

If a type of construction is selected which has a large dead load, the increase of load will increase the cost of the foundations. The percentage of increase in foundation cost due to adding load will be maximum in the case of spread foundations and minimum in the case of cylindrical piers. The greater increase in the case of spread foundations is due to the fact that while the horizontal area of the footing increases about in proportion to the increase in load, the depth must also increase, so that the increase in cost is more than proportional to the increase of load. In the case of pile foundations, the number of piles increase almost in direct proportion to the increase of load but the caps increase more than proportional to the increase in load; therefore, with pile foundations the increase in cost is more than proportional to the increase in load, but the proportional increase is not as great as in the case of spread foundations. In the case of cylindrical piers, the sectional area of the piers will increase in proportion to the increase in load, but as the unit costs for the larger piers are less, the increase in cost will be less than proportional to the increase in load. When cylindrical piers are to be used, saving can be made in the foundations by increasing the spans, thereby decreasing the number of piers required and increasing their sizes.

A complete analysis of cost should take into consideration the foundation costs as well as the cost of columns and floor construction.

Columns

Economy of space is involved in a consideration of relative economy of columns as well as actual cost of construction, as the sizes of various types of columns vary materially.

The following table is a list of common types of columns in the order of size, the larger being given first:

1 Rodded columns of Reinforced Concrete.

2 Spiral columns of Reinforced Concrete.

3 Structural Steel Fireproofed by Hollow Clay Tile.

4 Structural Steel Fireproofed by Concrete.

In some cases, for large loads, the size limitations require the use of one of the more expensive types of columns.

The following table is a list of the above types of columns arranged in order of cost, the most expensive being given first:

1 Structural Steel Fireproofed by Hollow Clay Tile.

2 Structural Steel Fireproofed by Concrete.

3 Spiral columns of Reinforced Concrete.

4 Rodded columns of Reinforced Concrete.

It will be noted that the two above tables are arranged about in reverse order.

The following variables affect the cost of concrete columns: (1) Reinforced concrete columns increase in cost as the amount of steel is increased and the amount of concrete is decreased. This is true because compressive stresses are more cheaply carried by concrete than by steel. (2) Reinforced concrete columns increase in cost as the proportions of cement are decreased, the additional cement increasing the allowable unit stresses more rapidly than the extra cement increases the cost of the concrete.

Columns of any size are usually considered by the owner as a necessary evil; therefore, he is usually willing to spend some extra money in order to keep the number and sizes of columns to a minimum. In a few instances we have taken alternate figures on structural steel columns encased in concrete and on reinforced concrete columns. In the majority of such cases, the owner decided that the larger columns were not so objectionable when he knew the saving in cost that was possible by their use.

Floor Construction

No attempt will be made to discuss all of the different types of floor construction that have been proposed or used. Even those in common use with the various possible combinations form quite a large list.

The following list covers most of the types of fireproof construction in common use:

1 Structural steel frame construction with the following types of floors:
- (a) Hollow clay tile arches.
- (b) Reinforced concrete joists with clay tile fillers.
- (c) Reinforced concrete joists with gypsum tile fillers.
- (d) Reinforced concrete joists with permanent metal fillers.
- (e) Reinforced concrete joists with removable wood or steel forms.
- (f) Solid reinforced concrete with one-way reinforcing.
- (g) Solid reinforced concrete with two-way reinforcing.

2 Reinforced concrete frame construction.

Reinforced concrete construction is used in connection with all the above except hollow clay tile arches.

3 Reinforced concrete flat slabs are used in the following forms:
- (a) Two-way reinforcing.
- (b) Three-way reinforcing.
- (c) Four-way reinforcing.
- (d) Combination of the two and four-way reinforcing.
- (e) Circular reinforcing.
- (f) Combination of two-way with depressed panels or tile joist construction.

The weights of the various types of floor construction for average loads and spans are approximately in the following order, starting with the lighter:

1 Hollow clay tile arches between steel beams.

2 Reinforced concrete joists with removable forms.

3 Reinforced concrete joists with permanent metal forms.

4 Reinforced concrete beam with slabs of about 3" thickness with beams spaced to develop the slab.

5 Reinforced concrete joists with gypsum tile fillers.

6 Reinforced concrete joists with hollow clay tile fillers.

7 Flat slab construction.

8 Two-way reinforced solid slabs with girders on column centers.

9 One-way reinforced solid slabs with girders on column centers.

Each of the different types will be treated by a general description and a discussion of their advantages, disadvantages and adaptability.

Hollow Clay Tile Arches

Tile arches are usually supported by steel beams with rod ties from beam to beam to take the thrust of the arches. Concrete fill is placed on the tile to receive the finished floor of wood or other material.

SEGMENTAL ARCHES

Figure one (1) shows a section of a Segmental Tile Arch.

Advantages:

Segmental arches are seldom used, but are more suitable for long spans and heavy loads than the flat tile arches.

Disadvantages:

It is difficult to fit the tile around the tie rods, more top filling is required and they form no plaster base for flat ceiling below.

Adaptability:

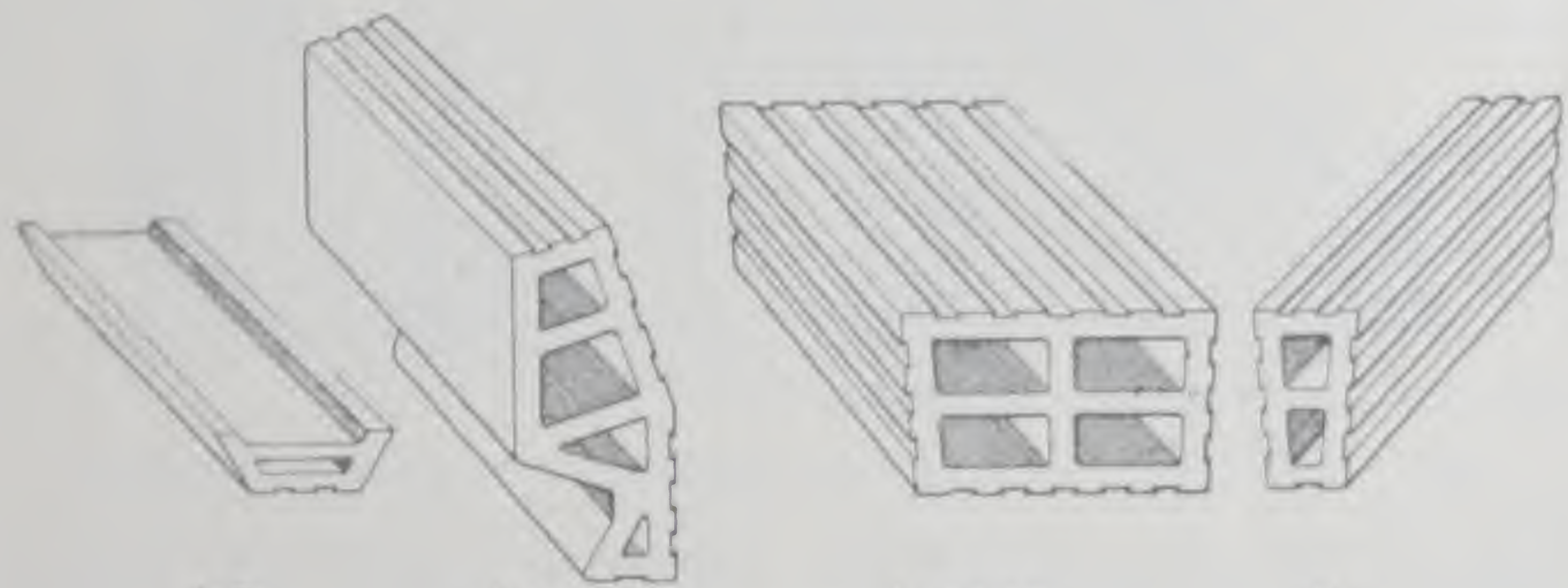
They should be used only for heavy loads such as warehouses, where no flat plastered ceilings are required.

FLAT HOLLOW TILE ARCHES

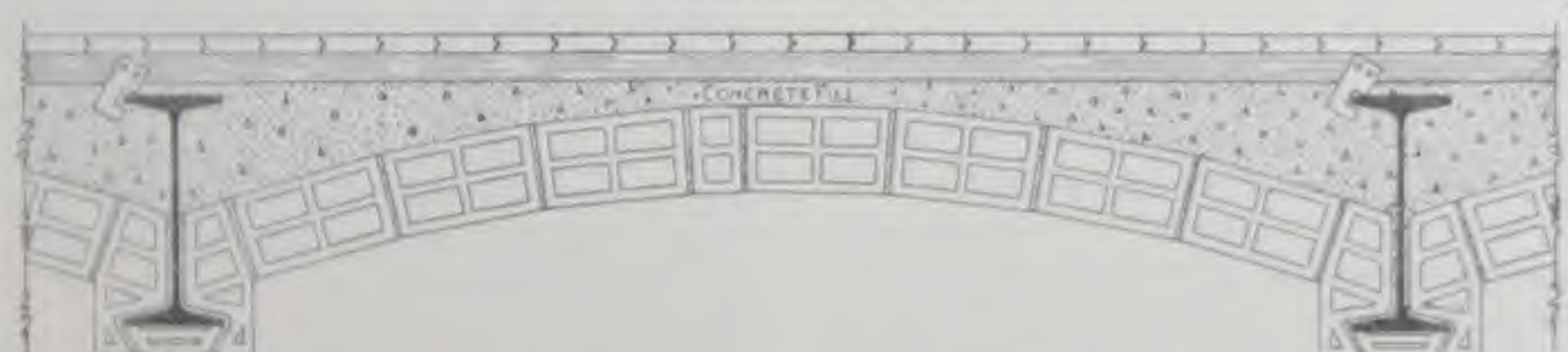
Figure two (2) shows a section of a Flat Hollow Tile Arch.

Flat tile arches are usually selected of such depth so that the structural steel beams will be entirely concealed in the floor construction. They are of two types, side and end construction, with combination of the two.

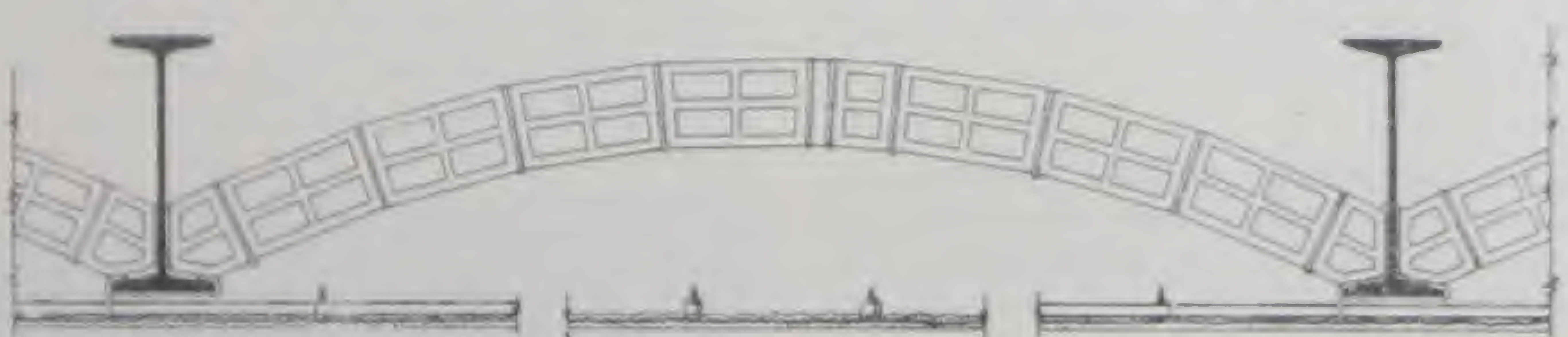
The side construction has the cells running parallel to the supporting beams. The end construction has the cells running at right angles to the supporting beams. The more common type is a



TYPICAL SHAPES

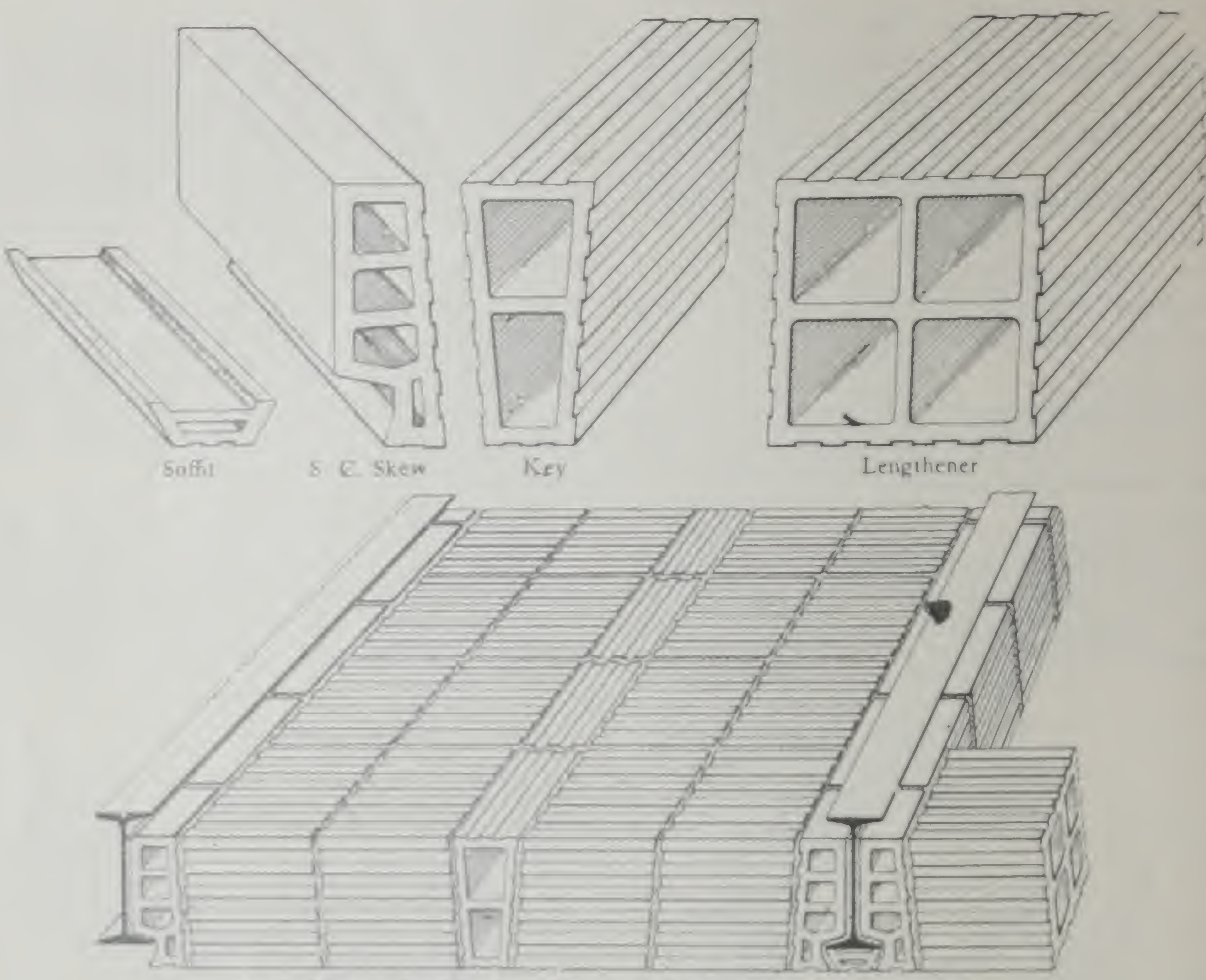


Typical Section—Standard Segmental Arch. Cinder Fill and Wood Floor in Place



Typical Section—Without Beam Protection. Used in Connection with Suspended Metal Lath Ceiling

FIG. 1—SEGMENTAL TILE ARCHES HAVE GREAT STRENGTH BUT HAVE CERTAIN DISADVANTAGES IN CONSTRUCTION.



Typical Span - Combination of End and Side Construction Flat Arch

FIG. 2—FLAT TILE ARCHES ARE ADAPTABLE TO HIGH BUILDINGS.

combination of the two, consisting of side construction skew backs, and key blocks with end construction tile between.

Advantages:

The structural steel and tile arches can be erected with great rapidity after the material is delivered on the ground. Construction can be carried on during the entire year without requiring unusual precautions in cold weather to prevent damage. The construction is of light weight and can readily be changed if required, without affecting the integrity of the structure as a whole.

Disadvantages:

The construction is very expensive. The structural steel does not have the best fire protection and very little if any protection from corrosion.

Adaptability:

The tile arch construction is adapted to high buildings where the live loads are small, such as office buildings or hotels.

Reinforced Concrete Joist Construction

Joist construction consists of reinforced concrete joists of varying depths and widths, depending on the loads and spans, with a thin concrete slab spanning between the joists. The space between the joists is formed by clay, gypsum or steel tile, or is formed by removable forms which do not form a permanent part of the construction.

Advantages:

Joist constructions have the advantage of the strength and stiffness of deep slabs with a great reduction in the amount of steel and concrete. The hollow spaces provided between the joists have considerable value for heat and sound insulation. It is usual practice to fireproof any structural steel used in connection with joist construction with concrete, thus affording the best possible protection for structural and reinforcing steel against fire or corrosion.

Disadvantages:

The concrete sections are thin and re-

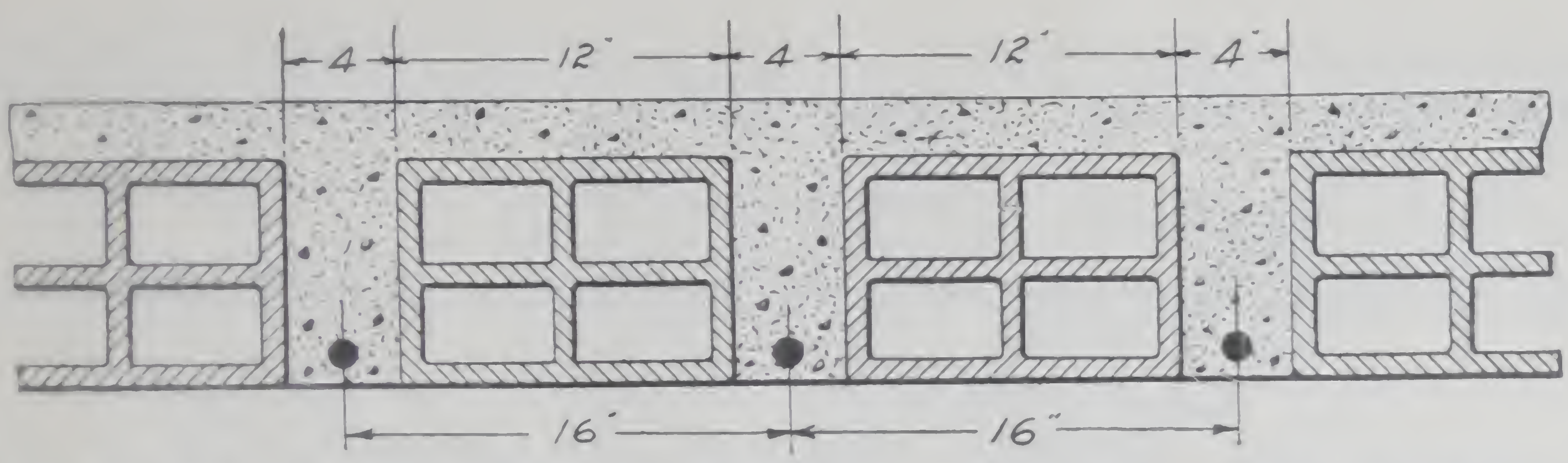


FIG. 3—CLAY TILE FILLERS ADD TO THE STRUCTURAL STRENGTH WHEN USED WITH CONCRETE JOISTS.

quire extreme care in the summer to guard against premature drying and in the winter to prevent freezing. The thin concrete sections are not adapted for concentrated loads. The reinforcement in the top slabs is of light section and difficult to keep in place during concreting operations.

Adaptability:

The joist type of construction is principally adapted to light loads and long spans where large concentrated loads are not encountered.

Reinforced Concrete Joists with Hollow Clay Tile Fillers

Figure 3 shows a section of Concrete Joist Construction with Hollow Clay Tile Fillers.

The standard width of the clay tile filler is twelve inches and the maximum depth is twelve inches. The concrete josts vary from four inches to six inches in width and the concrete covering over the tile is one and one-half inches or more.

Advantages:

The clay tile is assumed to act with the concrete sections and therefore adds to the structural strength, which is not the case for other types of joist construction. The bottoms of the clay tile and concrete joists form a satisfactory base for plaster.

Disadvantages:

The dead weight is somewhat higher than tile arch construction and the other types of joist construction. The difficulty of sealing the joints between the tile so as to exclude concrete from the inside of the tile may increase the dead load an unknown amount and also increases the cost an amount which cannot be predetermined. Due to the absorbent qualities of clay tile, great care must be exercised to prevent the concrete from being robbed of water, thereby greatly reducing its strength.

Adaptability:

This type of construction has about the same adaptability as the other types of joist construction, except that it is not suitable for as long spans as the other types.

FIG. 4—GYPSUM TILE MAKES A LIGHT FILLER BUT REQUIRES CAREFUL HANDLING.

Reinforced Concrete Joists with Gypsum Tile Fillers

Figure 4 shows the above type of construction. The standard width of gypsum tile and all standard joist construction except the clay tile is approximately twenty inches. The joists vary from four to six inches in width with varying depths as required by spans and loads. The concrete top slab should not be less than two inches thick.

Advantages:

Gypsum tile forms a light filler and provides a satisfactory base for plastered ceiling. It is somewhat lighter than clay tile construction and suitable for somewhat longer spans. The tile can readily be cut to fit conditions in the field.

Disadvantages:

The tiles require careful handling to prevent breakage and excessive rejection or patching to prevent waste of concrete which would increase the dead weight and cost.

Adaptability:

The construction is adaptable for long spans and, as in the case of all joist con-

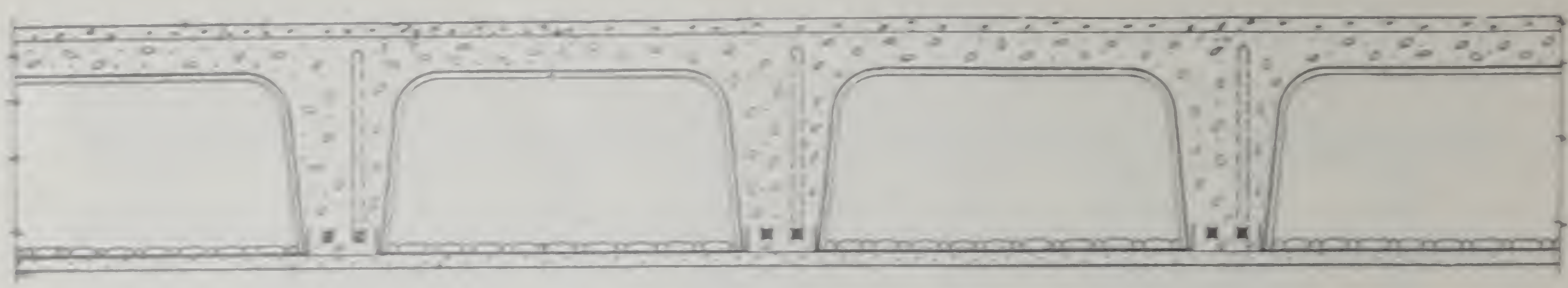


FIG. 5—FILLERS ARE SOMETIMES MADE OF METAL WHICH GIVES A LIGHTER STRUCTURE.

struction with plastered ceilings, has considerable heat and sound insulation properties. The gypsum tile adds somewhat to the insulation on account of its insulating properties.

Reinforced Concrete Joists with Permanent Metal Tiles

Figure 5 shows joist construction with permanent metal tile. The size of concrete sections is about the same as with gypsum tile construction, except that tapered end tiles are available to increase concrete sections near the support.

Advantages:

This form of construction has the advantage of being lighter in weight than clay tile or gypsum tile construction. If properly designed and installed, no appreciable leakage of concrete will occur.

The tapered tiles permit increasing the concrete sections near the support to properly take care of shearing and negative bending stresses.

The bottom of the tiles consists of perforated metal which forms a plaster base and, therefore, requires no metal lath after the concrete work is completed.

Disadvantages:

The metal tile adds nothing to the fireproofing of the construction.

As the tiles are not salvaged, the tendency has been to design the tiles so light that they easily distort, thereby increasing the dead load and cost.

Adaptability:

This type has the same adaptability as other types of joist construction and is lighter in weight than clay or gypsum tile construction.

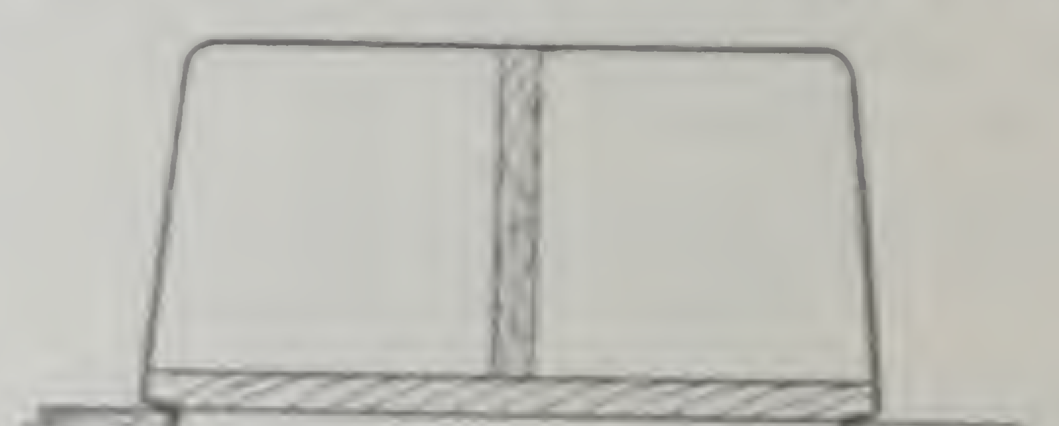
Reinforced Concrete Joist Construction with Removable Forms

The concrete sections are about the same as other types of joist construction except clay tile, and the forms are made of wood or steel. Tapered end sections are also available.

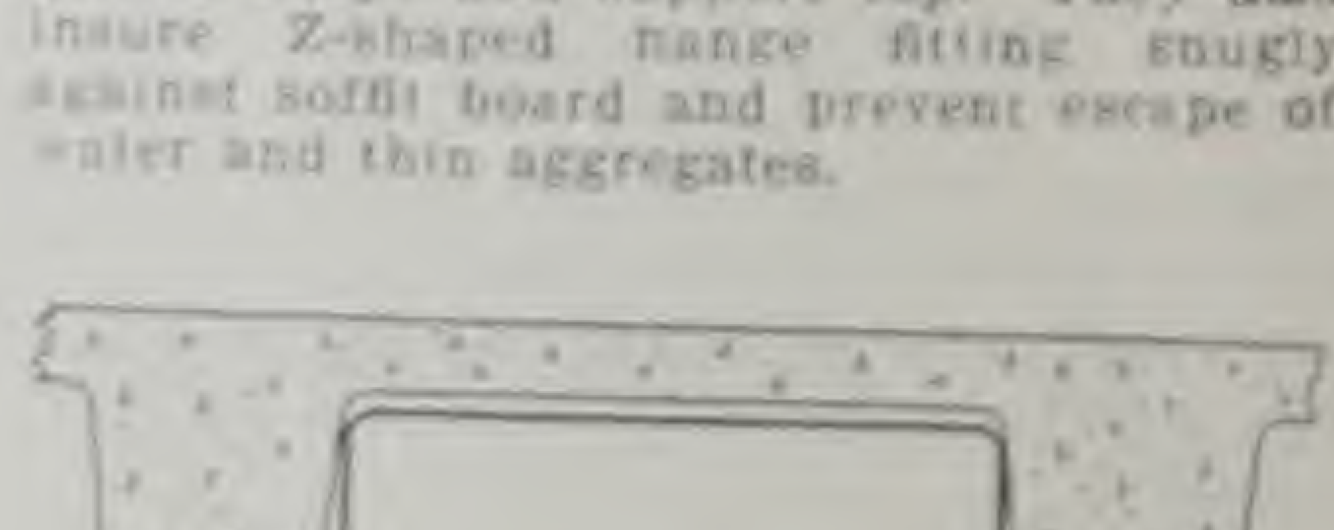
Figure 6 shows removable steel forms, and Figure 7 shows removable wood forms.

Advantages:

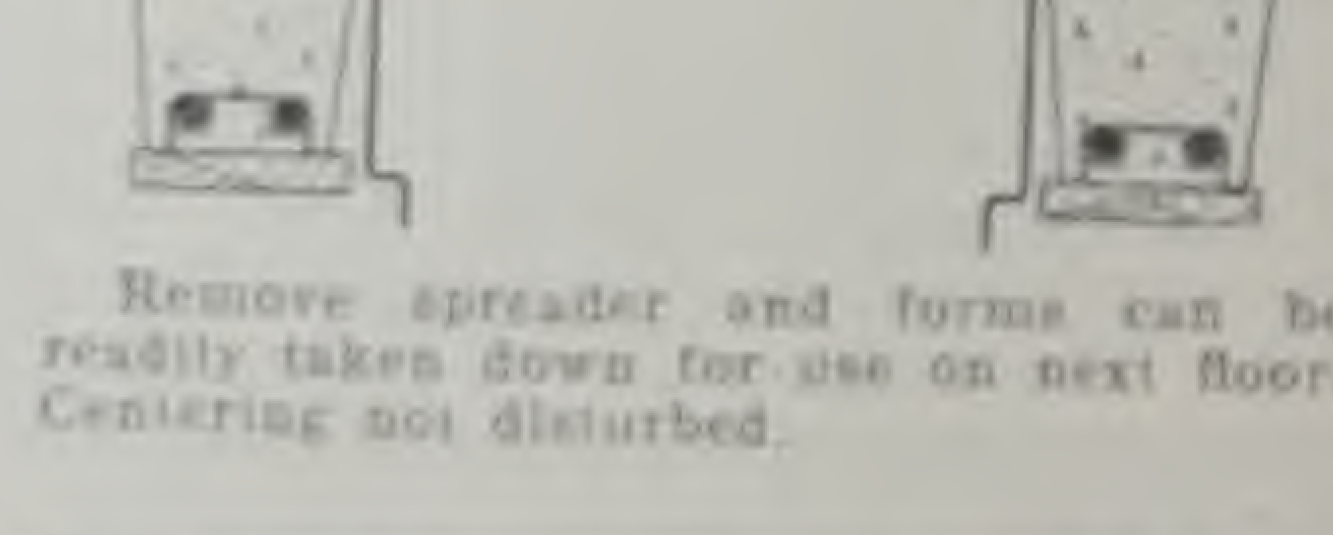
On account of the re-use of the removable forms, they are usually made more rigid than the permanent steel forms; therefore, the concrete sections are very nearly as designed. This is particularly



T-shaped spreaders bring form to required shape and support top. They also insure Z-shaped flange fitting snugly against soffit board and prevent escape of water and thin aggregates.



Remove spreader and forms can be readily taken down for use on next floor. Centering not disturbed.



Form removed and metal lath ceiling in place.

FIG. 6—REMOVABLE STEEL FORMS ARE RIGID AND FURNISH THE LIGHTEST TYPE OF JOIST CONSTRUCTION.

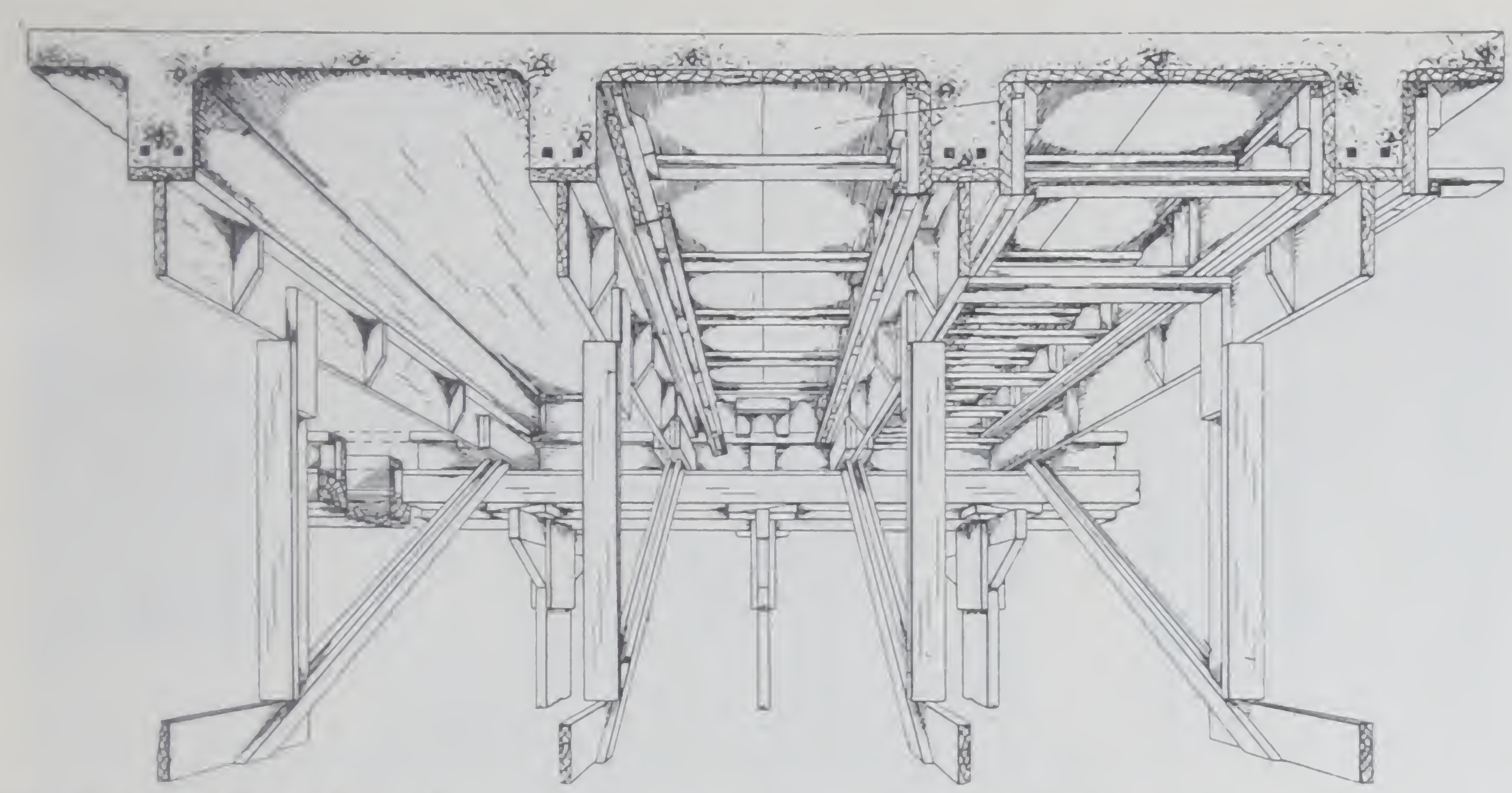


FIG. 7—REMOVABLE WOOD FORMS PERMIT EASY INSTALLATION OF OUTLET BOXES, INSERTS, ETC.

true of wood forms. All surfaces of the concrete work can be inspected after the forms are removed, and any poor work corrected.

It is the lightest type of joist construction, as no forms or tile are left in place.

If the ceiling is to be suspended some distance below the bottoms of the joists, it can be readily accomplished in this type of construction without wasting the plaster base at the bottoms of the joists provided in the other types of joist construction. The wood forms have the advantage of permitting the more convenient and rigid attachment of inserts, electrical outlets and sleeves to the forms.

Disadvantages:

In some localities, labor conditions are such as to make it desirable to eliminate the metal lathers from the work if possible.

Adaptability:

It has the same adaptability as the other types of joist construction which use the larger tiles.

The cost is not far different from permanent steel tiles and one or the other may prove cheaper, depending on the local conditions, size of structure (which determines the number of times the forms can be re-used) and the personal preference of the contractor.

All the joist types can be used with structural steel or reinforced concrete frames.

The reinforced concrete frame is much cheaper than steel frame construction for all ordinary spans and loading. The size of the beams and girders is somewhat larger in the case of reinforced concrete and for very long spans it is usually advisable to substitute structural steel girders.

One-Way Reinforced Slabs With Closely Spaced Beams

A very light and economical type of construction results from using a three-inch or three-and-one-half-inch slab with the beams spaced as far apart as the strength of the slab will permit. Girders are placed in one direction on column centers.

Advantages:

All concrete sections are used to the best advantage structurally. The extremely thin sections used in joist construction are eliminated. It has more strength to resist concentrated loads. Its dead weight will not materially exceed the joist construction. Heavier reinforcement is used in the slabs and is, therefore, more readily held in place.

As the development of gypsum tile and steel tile has increased the spacing of joists from twelve inches clear used for clay tile to approximately twenty inches used for other types, it will not be sur-

FIG. 8—ONE-WAY REINFORCED SLABS BETWEEN GIRDERS ON COLUMN CENTERS ARE NOW SELDOM USED.

prising if the joist construction of the future will have the joists three feet or more apart.

Disadvantages:

No standard forms are now available for the wider spaced joists or beams. The construction will be somewhat deeper than ordinary joist construction.

Adaptability:

It is applicable where joist constructions may be used and is also suitable for somewhat longer spans.

One-Way Reinforced Concrete Slabs Between Girders on Column Centers

This type is very heavy and expensive for ordinary spans and is seldom used now except by engineers or architects who do not carefully analyze their work. The thicker slab which is required for this type of construction has the advantage of better resisting concentrated loads. (Figure 8 shows this type.)

Two-Way Reinforced Concrete Slabs Between Girders on Column Centers in Both Directions

This type is somewhat lighter and more economical than the one-way, if the panels are approximately square. It has the advantage of having girders in both directions to more thoroughly brace the structure.

Both of the above types have been largely supplanted by flat slab construction.

Flat Slab Types

Figure 9 shows the arrangement of the reinforcing steel in the different types and a cross section which is typical for all types of flat slab construction.

No effort will be made to prove which one of the various types is the best as this might start a discussion that would take up the entire evening and eliminate entirely the broader discussion which it is desired to bring out. All of the different types have enlarged capitals which form broad supports for the slab and shorten the clear spans.

With the exception of the three-way construction, all the types will appear the same after the structure is completed. The essential difference is the arrangement of the reinforcing. Any one of the systems will give satisfactory service if the reinforcing and concrete is proper in amount and in location to properly resist the bending, shearing as well as temperature and shrinkage stresses. The different systems will be briefly described.

TWO-WAY FLAT SLABS

Two-way flat slabs have all of the reinforcing arranged in two directions parallel to the lines passing through the column center.

The main bands pass over the column heads and occupy the space extending about one-fourth of the span in each direction from the column centers. The re-

inforcing is in the top of the slab over the column heads and in the bottom of the slab between column heads. The mid-bands occupy the space between the main bands and the reinforcing is in the top of the slab over the main bands and in the bottom of the slab in the central portion of the panel.

THREE-WAY FLAT SLABS

The three-way construction requires a different arrangement of columns. The columns are so arranged that the panels

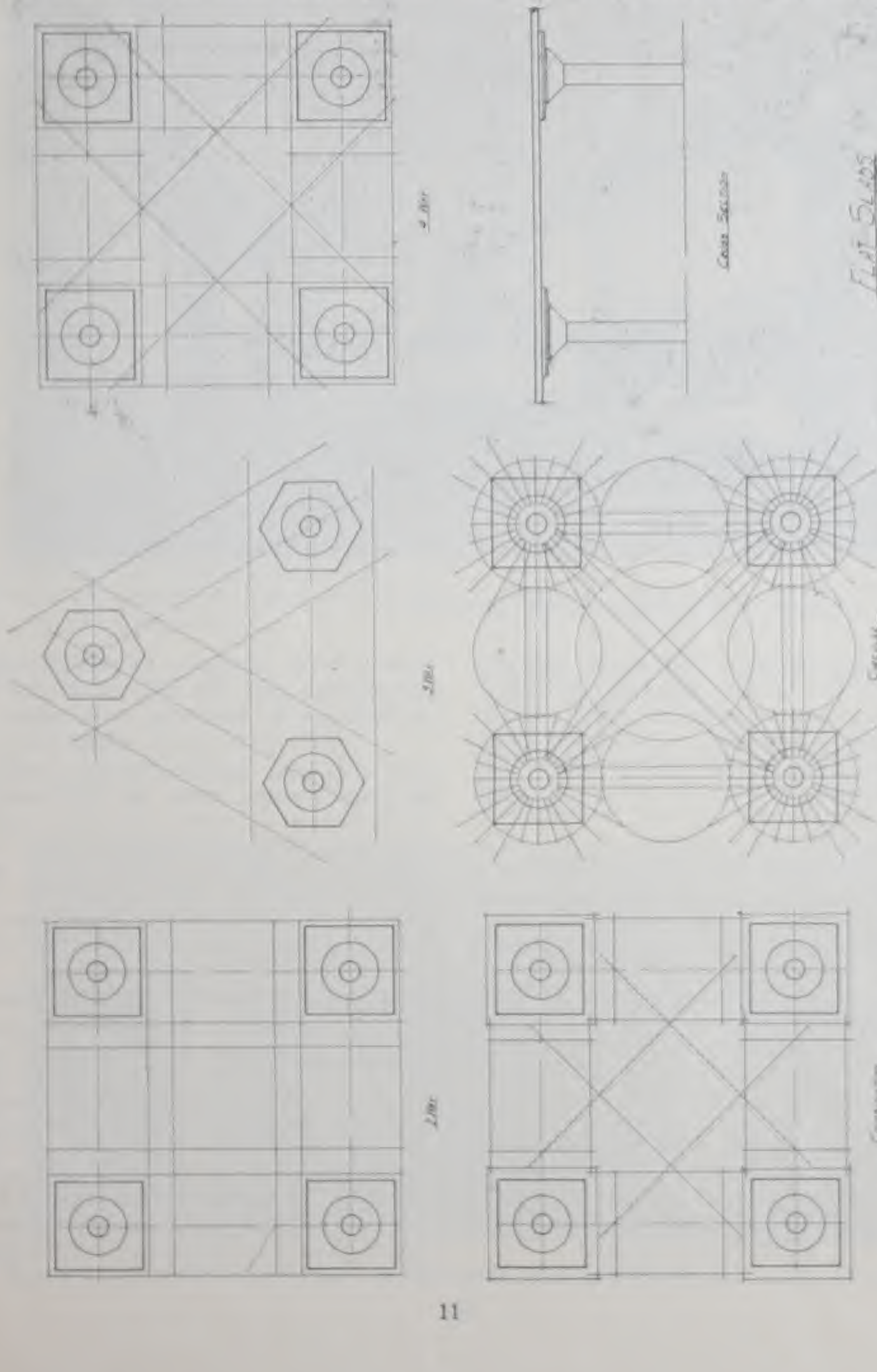


FIG. 9—SEVERAL TYPES OF REINFORCING MAY BE USED IN FLAT SLAB CONSTRUCTION.

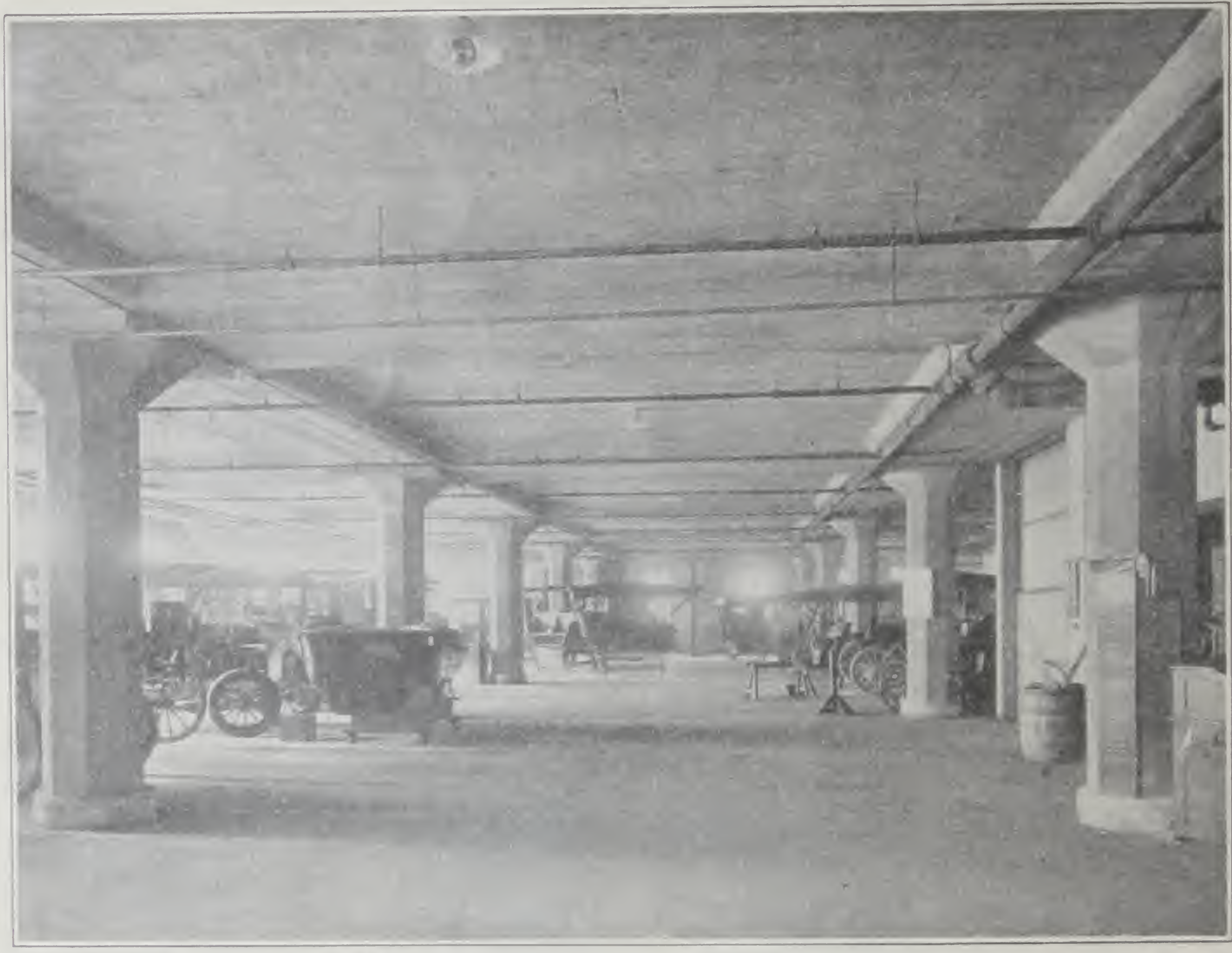


FIG. 10—DEAD LOAD MAY BE REDUCED BY USING THE MODIFIED FLAT SLAB USING A THINNER CENTER SECTION.

are approximately equilateral triangles. Three sets of bars are used, the bands of bars being of sufficient width to cover the entire slab area. All of the bands of bars pass over the column heads. The reinforcing is near the top of the slab over the columns and near the bottom of the slab between columns.

FOUR-WAY FLAT SLABS

The four-way reinforcing consists of bands of bars passing from column to column along both direct and diagonal lines, making bands in four directions. As in the case of the three-way, all bands pass over the column heads. All bars are near the top of the slab over the columns and near the bottom of the slab between the columns. An additional band of bars is placed near the top of the slab at right angles to and above the direct bands of bars in the central portion between columns.

COMBINATION TWO AND FOUR-WAY FLAT SLABS

In this type the reinforcing over the column heads conforms to the two-way construction and the rest of the panel is similar to the four-way construction.

CIRCULAR FLAT SLABS

In this type the reinforcing occupies the same regions in the top and bottom of the slabs as is found in the other types. The main reinforcing consists of bars arranged in concentric circles or in the form of involutes. This system has, in addition to the circular reinforcing, a band of straight bars at right angles to and over the direct column lines.

Modification of Standard Flat Slab Types

Modification of the flat slab types may be made by reducing the thickness of the central portion of the panel, as shown by Figure 10. Also, joist construction may be used in the central portion of the panel or solid girder slabs may be used on column centers in one direction with one-way joist construction between the girder slabs. The appearance of the finished construction after plastering is the same, but the dead load is materially reduced.

Flat Slab Construction

Advantages:

The smooth ceilings are advantageous for lighting, ventilation, arrangement of sprinklers and mechanical equipment including shafting. Figure 11 shows a typical flat slab interior.

The construction is quite shallow, allowing a material reduction in the height of the building if the same clear story heights are maintained. When comparing the relative building height for flat slab and beam and girder construction, we find that the saving in height is about three-fourths of one story in a seven-story building.

Flat slabs readily take care of very large concentrated loads.

The elimination of beams and girders make a structure more fireproof, as there are few corners for the flames to attack.

For average spans and ordinary loadings, the flat slab construction is by far the cheapest type that can be built. The amounts of concrete and steel are much less for flat slabs than for beam and girder construction. Expensive stirrups are almost entirely eliminated. The form cost is low on account of the wide expanse of flat deck construction.

Disadvantages:

The construction is heavier than joist construction for light loads and the longer spans.

The enlarged column capitals are objectionable for some types of buildings.

Changes cannot be made readily after the structure is completed.

The solid slab does not provide much insulation for sound and heat.

Adaptability:

The maximum economy for flat slabs occurs with spans approximately twenty ft. by twenty ft. and for heavy live loads. The relative economy decreases as the spans increase and the live loads decrease. On account of its many advantages, flat slab construction has practically supplanted beam and girder construction for the heavier loads and average spans.

Conclusion

There are so many variables in building construction that no definite rules can be given which will permit a designer to pick out at once the type of construction which should be used for any particular case.

For a specific building, however, so many of the variables can be eliminated that by estimating the approximate quantities and cost of two or three types of construction, the most economical construction can be determined.

With the type of foundation, spacing of columns, clear story heights, live loads and the use of the building determined, the kinds of fireproof construction which should be investigated will be reduced to a very small number.

Acknowledgment is made to National Fireproofing Co., Concrete Steel Co., The Goldsmith Metal Lath Co., and Bergendohl and Archer, Inc., for the use of illustrations contained in this paper.

FIG. 11—A TYPICAL FLAT SLAB CONSTRUCTION.

Analysis of Cost of Types of Fireproof Construction

By Arthur F. Klein,* M. W. S. E.

Presented March 24, 1924

This paper gives unit costs of different methods of fireproof construction of three types of buildings. Four types of construction for a sixteen-story hotel, three for a light manufacturing building and three for a heavy warehouse are analyzed. It is noticeable that for each of these buildings, there is a type of construction that stands out as cheaper than the rest. Other factors such as speed of construction, accommodation of utilities, etc., are not evaluated in this analysis. These are the more common of the types described by Mr. Post in the preceding paper. He has given the relative fireproofing values and construction features while this paper reduces the cost of each to a unit basis.

In making a comparison of the cost of the various types of floor systems which have been described by Mr. Post, it is not the purpose of this paper to attempt to prove the advantage of any particular design, but rather to get at a fair and average cost of the various types presented.

Unit prices have been arrived at by taking the current market price of materials delivered by truck and the wages paid for labor as of today, not taking into consideration premium wages or unusual rush conditions, but rather the ordinary run of work of this character under normal conditions.

Sixteen-Story Hotel

Types "A", "B", "C", "D" are paneled sections of a 16-story and basement hotel, live load, 50 lb., partitions on column centers, panels 18 ft. x 24 ft., story heights 11 ft., floor to floor, with plastered ceilings.

The designs for types "A", "B", "C", and "D" were prepared by Frank Randall (M. W. S. E.)

TYPE "A":

Type "A" is of structural steel design, steel columns, 20-in. steel girders and 12-in. steel beams, with 12-in. tile arches, two-coat plastered ceilings applied direct to the under side of the arches, and 4-in. concrete floor fill with monolithic cement finish.

*Vice-President, R. C. Wieboldt Co., Chicago.

The structural steel was estimated on a basis of $90.00 per ton, f. o. b. cars, Chicago, plus $20.00 per ton for erection, or a total of $110.00 per ton erected in place. The structural steel weighs an average of 17 lb. per square foot.

The total height of the building from the basement floor to roof of the hotel is 187 feet.

The cubic contents of one panel, 18 ft. x 24 ft. x 187 ft. amount to 80,784 cubic feet, with 7,344 square feet of floor area.

The total cost of the steel construction as shown by the detailed estimate, Type "A", amounted to $13,150.06, or a unit cost of 16.3c per cubic foot and a unit cost of $1.79 per square foot of floor area.

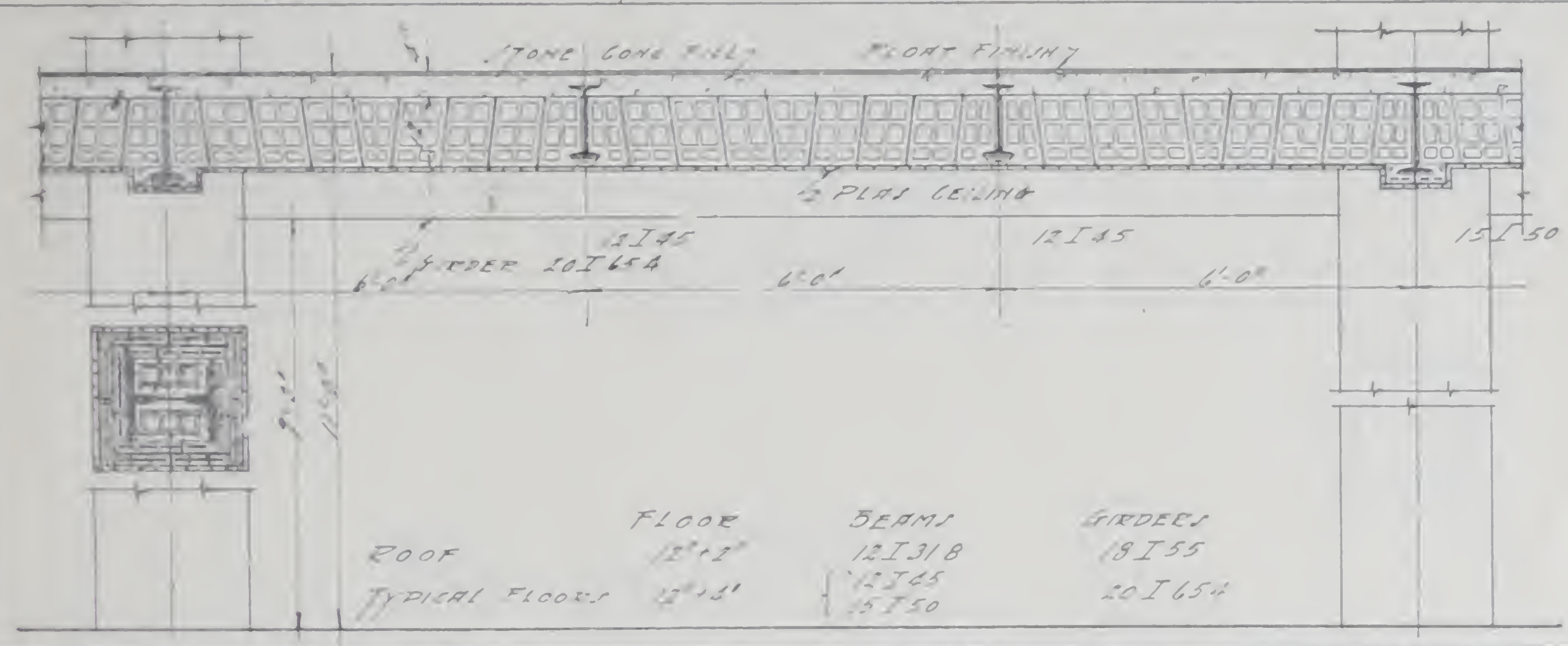
TYPE "B":

Type "B" is a reinforced concrete design for the 16-story hotel building, using concrete slabs, concrete joists, metal tile domes, concrete girders and concrete columns. This is commonly known as the "Tin Pan" system.

In arriving at the unit prices for the reinforced concrete, cement was estimated at $2.90 per barrel, less discount and less sacks, making a net price of $2.45 per barrel. Crushed stone and torpedo sand were estimated at a market price of $2.75 per cubic yard delivered by team. It was assumed that an adequate concrete mixing and distributing plant would

° TYPE A · STEEL & TILE °

PANELS 18'-0" x 24'-0" 11'-8" FLOOR TO FLOOR	· HOTEL · 16 STORIES & BASEMENT	50# L.L. 3" TILE PARTITIONS ON COLUMN CENTER LINES PLAS. CEILING



DESCRIPTION	QUANTITY	UNIT COST	COST
STRUCTURAL STEEL —			
COLUMNS, BEAMS & GIRDERS	123 396 LBS	.055	6786 78
TILE ARCHES & SHOE TILE	7344 CU FT	50	3672 00
COLUMN FIREPROOFING TILE	612 CU FT	50	306 00
TILE GIRDER COVERING	177 CU FT	80	231 20
CONCRETE FILL - 1:3.5 MIX	2376 CU FT	40	950 .40
CEMENT FINISH	7344 SQ FT	07	514 08
PLASTER	862 SQ YDS	80	689 60

TOTAL COST = $13 150 06

80,784 CU. FT. @ $.163
7,344 SQ. FT. @ $1.79

be installed and allowance made for sack loss and wasted concrete materials. Allowing for normal efficiency of labor, a unit price with a mix of one of cement, two of sand and four of stone was arrived at, of $12.50 per cubic yard for concrete in place, or approximately 44c per cubic foot.

Removable metal domes were used in this particular estimate and figured at a rental cost of 8c per square foot estimating the total area. No deductions for openings less than 100 square feet were made.

The slab forms were figured on a basis of three complete floors of forms, allowing for re-usage five or six times.

Lumber for forms was figured on an average price of $47.00 per thousand board feet.

The reinforcing steel is estimated at $60.00 per ton, base, f. o. b. Chicago, with a standard increase in price for sizes below base and with the following additional unit prices:

Standard bending	$ 6.00 per ton
Trucking	3.00 per ton
Bending stirrups	18.00 per ton
Detailed shop drawings....	3.00 per ton
Spirals	90.00 per ton

These latter unit prices represent the usual prices which have been charged in and around Chicago for the past one or two years.

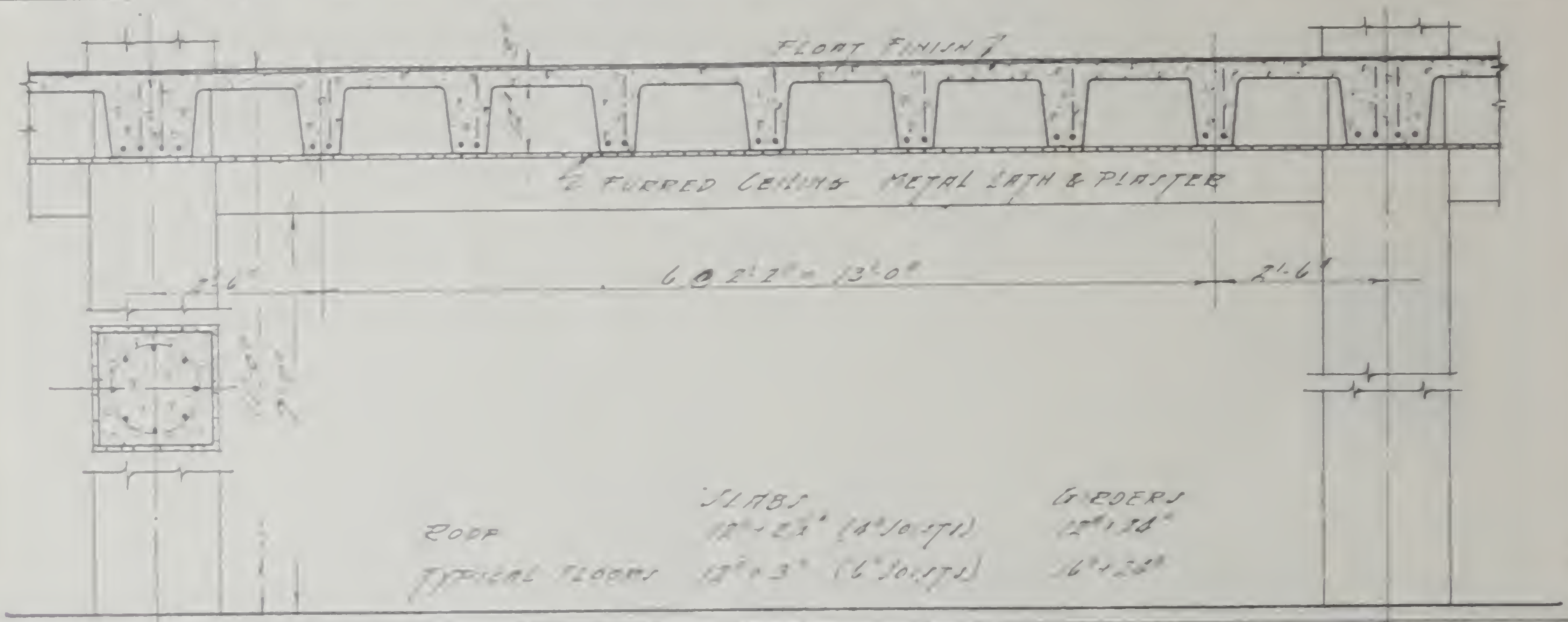
The erection of the reinforcing steel was estimated at an average price of $20.00 per ton. Figuring the steel at the various prices above quoted and dividing by the total amount of reinforcing steel the various unit prices for reinforcing steel installed in place were arrived at.

The concrete in the columns is of a richer mixture, being one of cement, one of sand, and two of stone. The additional cost of the cement amounted to $2.50 per cubic yard, or an increase in the unit price of approximately 10c per cubic foot, making a total of 54c per cubic foot for concrete, 1:1:2 installed in place.

The plaster finish consists of a metal

∘ TYPE B ∘ CONCRETE JOISTS ∘

PANELS 18'-0" × 24'-0" 11'-0" FLOOR TO FLOOR	HOTEL 16 STORIES & BASEMENT	50# LL 3" TILE PARTITIONS ON COLUMN CENTER LINES PLAS CEILING



DESCRIPTION	QUANTITY	UNIT COST	COST
FLOOR			
1:2:4 CONCRETE – SLABS, JOISTS & GIRDERS	4896 CU FT	.44	2154.24
METAL TILE	7344 SQ FT	.08	587.52
OPEN FORMS	7344 SQ FT	.23	1689.12
CLOSED FORMS (GIRDERS)	881 SQ FT	.35	308.35
REINFORCING STEEL	20,525 LBS	.047	964.68
COLUMNS			
1:1:2 CONCRETE	1388 CU FT	.54	749.52
FORMS	1878 SQ FT	.25	469.50
REINFORCING STEEL	9269 LBS	.053	491.26
CEMENT FINISH	7344 SQ FT	.07	514.08
METAL LATH & PLASTER	867 SQ YDS	2.10	1820.70
		TOTAL COST =	$9,748.97

80,784 CU FT @ $.120
7344 SQ FT @ $1.[illegible]

lath furred ceiling, furred direct to the underside of the concrete joists and the plastering three-coat work. The total cost of the metal lath ceiling plastered complete is figured at the current unit prices of $2.10 per square yard.

The cement finish is figured in all cases of a monolithic type and represents the additional cost of the materials and the labor, troweling and finishing, over the flat unit price of the concrete.

The total cost of the panel for Type "B" as shown by the detailed estimate under this heading is $9,748.97, or a unit price of 12c per cubic foot and a square foot price of $1.33.

TYPE "C":

Type "C" is the same type of 16-story hotel building using reinforced concrete construction, concrete slabs, concrete joists, with clay tile fillers, concrete girders and concrete columns. This is commonly known as "Combination Tile and Concrete Arch, Joist Type."

The cement finish is applied direct to the slab monolithically, the plastering, two-coat work, direct to the underside of the tile filler and concrete joists.

The 10-in. clay tile fillers are priced at a unit price of 25c each.

The slab forms are figured at an increased price of 2c per square foot over and above Type "B", the reason being that the joists are at 19-in. centers in the case of Type "C" as against 26-in. centers in the case of Type "B". Also, there is a slight increase in dead weight to be carried on account of the clay tile fillers.

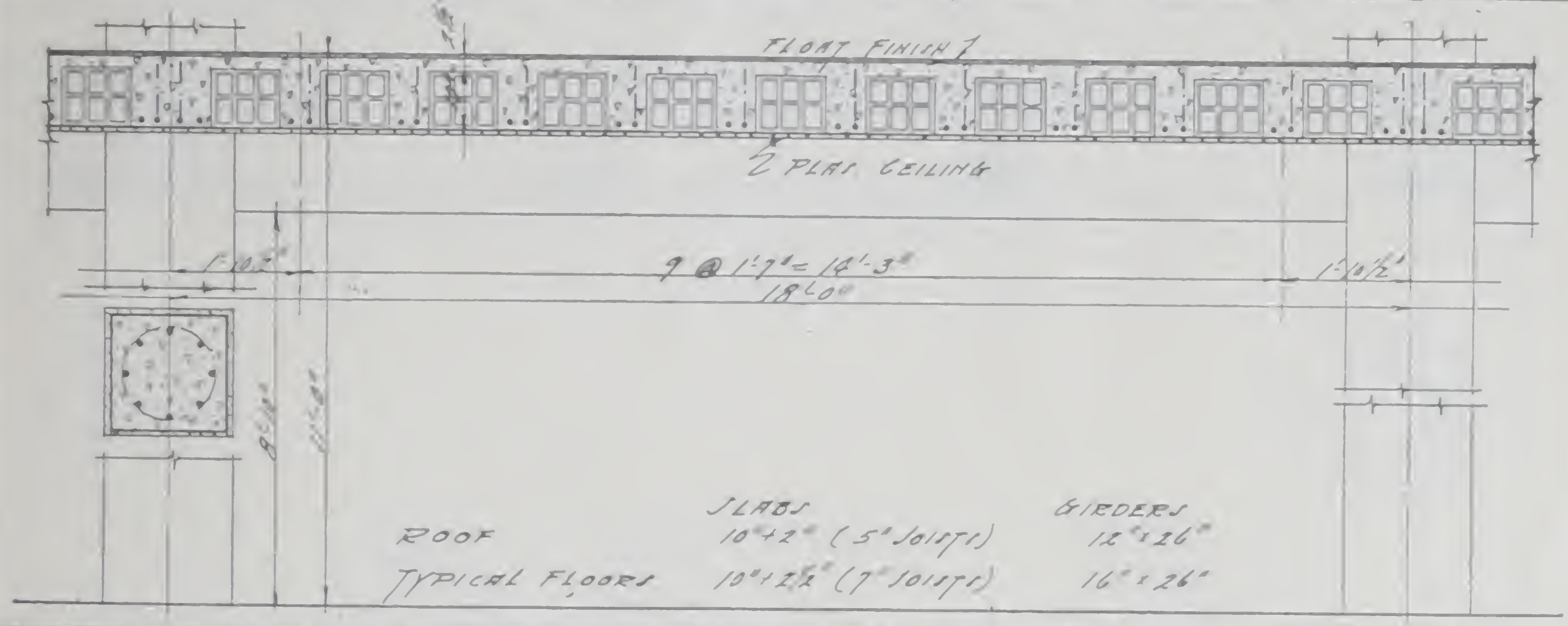
Reinforcing steel, concrete and cement finish are figured at the same unit prices as will be noted in the detailed estimate.

The plastering is figured at 90c per square yard for two-coat work. This is an increase of 10c per square yard over Type "A", the reason being that the plastering over the bottom of the concrete joists is more expensive.

The total cost of Scheme "C", as will be noted from the detailed estimate is

° TYPE C · TILE & CONCRETE °

PANELS 18'-0" x 24'-0" 11'-0" FLOOR TO FLOOR	· HOTEL · 16 STORIES & BASEMENT	50# L.L. 3" TILE PARTITIONS ON COLUMN CENTER LINES PLAS CEILING



DESCRIPTION	QUANTITY	UNIT COST	COST
FLOOR			
1 : 2 : 4 CONCRETE — SLABS, JOISTS & GIRDERS	4790 CU.FT	.44	2107.60
CLAY TILE	3948 PCS.	.25	987.00
OPEN FORMS	7,344 SQ FT	.25	1835.00
CLOSED FORMS (GIRDERS)	1089 SQ FT	.35	381.15
REINFORCING STEEL	26,358 LBS	.047	1238.83
COLUMNS			
1 : 1 : 2 CONCRETE	1469 CU FT	.54	793.26
FORMS	1981 SQ FT	.25	495.25
REINFORCING STEEL	12,355 LBS.	.052	642.46
CEMENT FINISH	7344 SQ.FT	.07	514.08
PLASTER	893 SQ YDS	.90	803.70
		TOTAL COST =	9798.33

80,784 CU FT @ $.121
7,344 SQ FT @ $1.33

$9,798.33, or a unit price of 12c per cubic foot and a square foot price of $1.33.

TYPE "D":

Type "D" is the same type of 16-story hotel building, reinforced concrete design, with concrete beams, 6 ft. centers, and concrete girders and columns.

The forms for the slabs in this instance are closed forms instead of open forms as in the case of Type "B" and Type "C" and are, therefore, priced at a higher unit. The forms for the girders and the beams are estimated on the contact area.

The concrete, reinforcing steel and cement finish are figured at the same unit prices as in Types "B" and "C".

The plastering consists of a suspended metal ceiling and on account of the fact that the joists are 6-ft. centers instead of 26-in. centers as in Type "B", the plastering and metal lath ceiling are estimated at a unit price of $2.25 per square yard, or 15c per square yard higher than for Type "B".

It will be noted from the detailed estimate that the total cost of Type "D" for the panel is $11,072.35, or a unit price of 13.7c per cubic foot and $1.51 per square foot.

CONCLUSION:

Considered solely from a standpoint of cost, Type "B" and Type "C" represent the most economical design and in so far as the cost is concerned, the totals for Type "B" and Type "C" are practically the same.

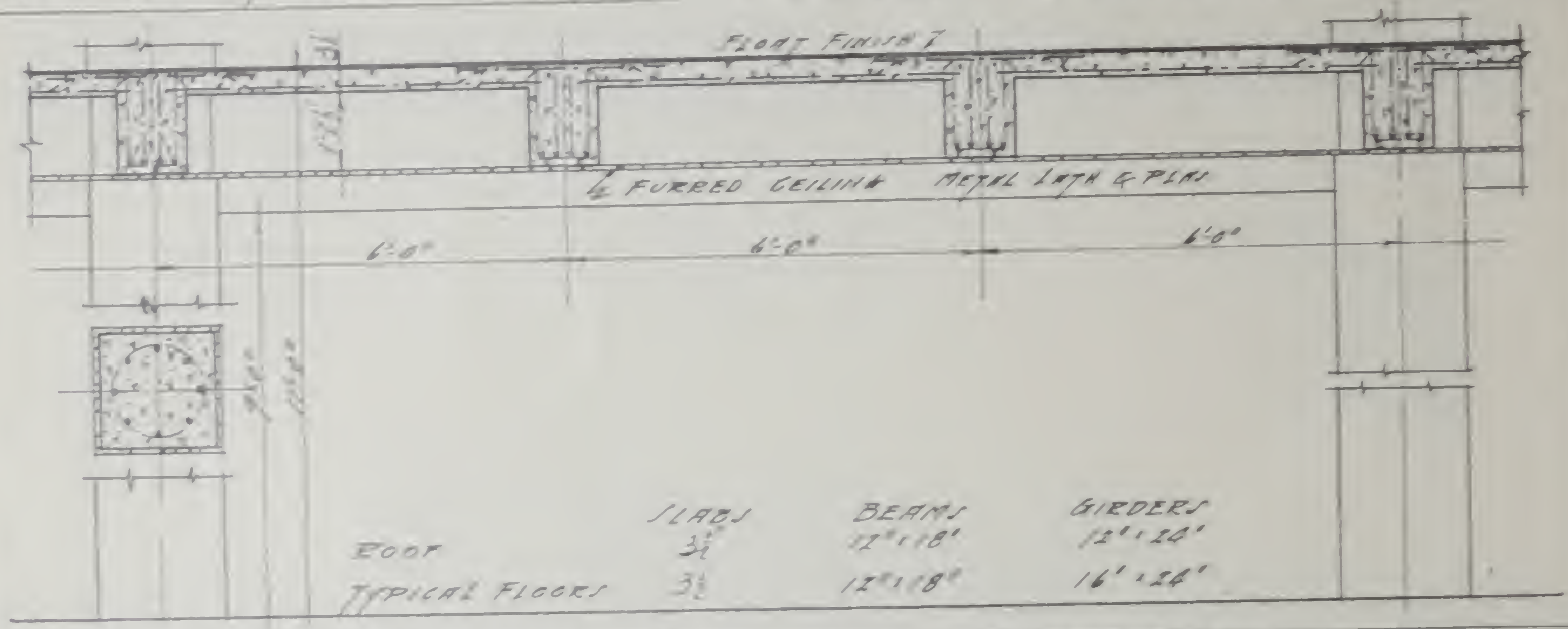
It would be my opinion from a builder's standpoint that Type "B" would have some advantages over Type "C". Space is allowed for pipes between concrete joists, the plastered ceiling is uniform and there is less danger of shrinkage cracks in the plastered ceiling than in Type "C". It has also been my experience that after a number of years the plastering discolors in the case of Type "C" and takes on a ribbed appearance where the concrete joists show through.

Light Manufacturing Building

The next types considered, "E", "F", and "G", are reinforced concrete designs for a light manufacturing building, six-

TYPE D · BEAM & GIRDER

PANELS 18'-0" x 24'-0" · 11'-0" FLOOR TO FLOOR | HOTEL 16 STORIES & BASEMENT | 50# L.L. 3" TILE PARTITIONS ON COLUMN CENTER LINES PLAS. CEILING



DESCRIPTION	QUANTITY	UNIT COST	COST
FLOOR			
1:2:4 CONCRETE — SLABS, BEAMS & GIRDERS	4546 CU FT	$ .44	$2,000.24
CLOSED FORMS (SLABS)	7344 SQ FT	.27	1982 88
CLOSED FORMS (GIRDERS)	5,502 SQ FT	.35	1,925 70
REINFORCING STEEL	20,360 LBS	.047	956 .92
COLUMNS			
1:1½:2 CONCRETE	1408 CU FT	.54	760 .32
FORMS	2,068 SQ FT	.25	517 00
REINFORCING STEEL	9,857 LBS.	.051	502 71
CEMENT FINISH	7,344 SQ FT	.07	514 08
METAL LATH & PLASTER	850 SQ YDS.	2.25	1,912 50

TOTAL COST = $11,072 35

80,784 CU FT @ $ .137
7,344 SQ FT @ $1 51

story and basement, live load 100 lb. per square foot, panels and column centers 20 ft. x 20 ft. story height 10 ft. in the clear.

These designs were prepared by John W. Musham, M. W. S. E., of the Condron Co.

TYPE "E":

Type "E" consists of a two-way slab and girder design.

Concrete and other materials, whereever possible, for uniform comparison, are priced at the same unit prices, not taking into consideration the fact that the rental and cost of concrete machinery would probably be higher per cubic yard on a six-story building than for a sixteen-story building, practically the same equipment being required in either case with much less volume in the case of the six-story building.

For slab forms it was estimated that two complete floors of slabs would be required, giving a re-usage of 3½ times. The forms are priced at a slight increase over Type "D" due to the heavier load requirements.

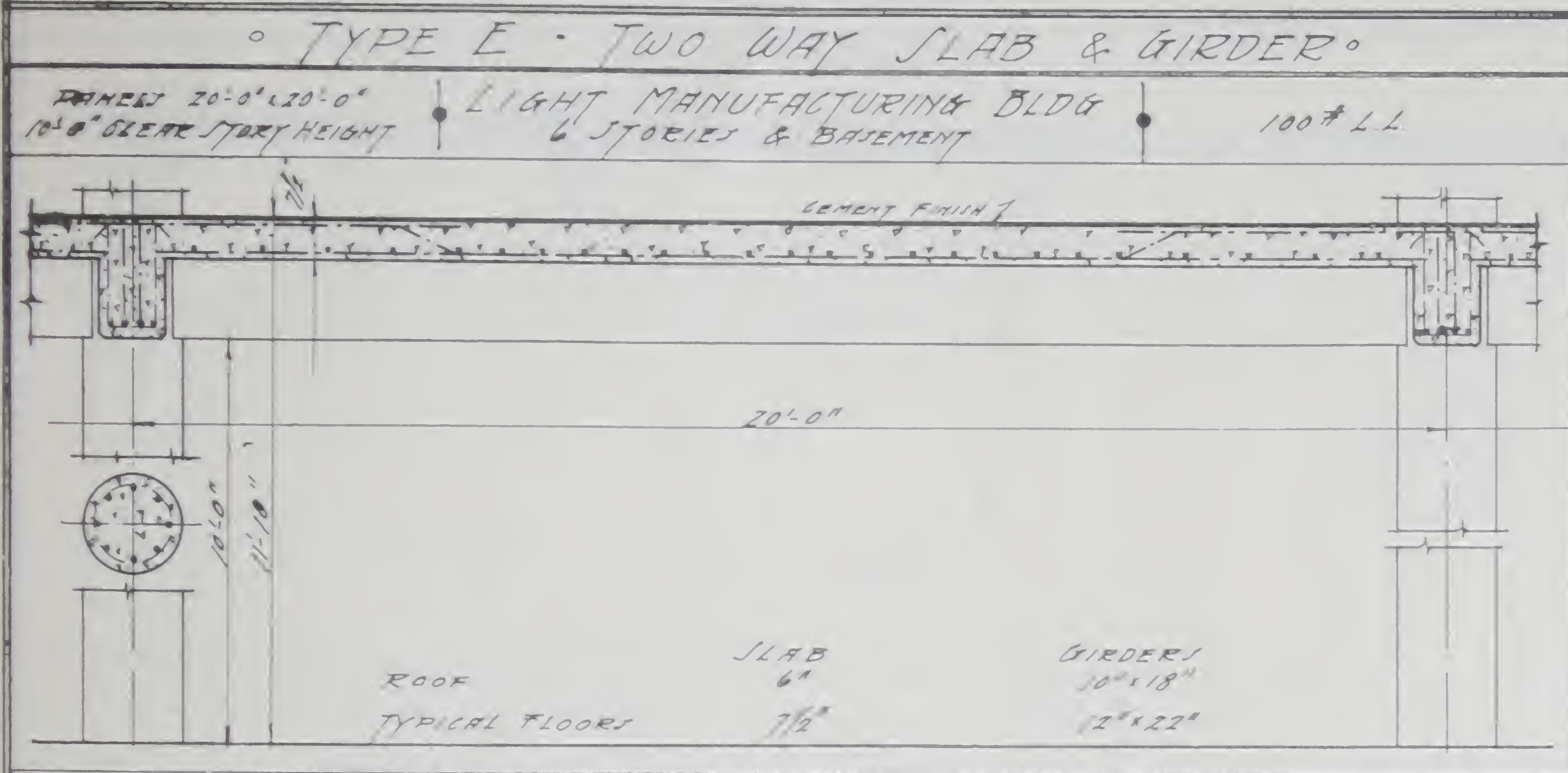
The concrete in the columns is of 1:2:4 mix and priced at the same unit price for the reasons stated, as will be noted in the detailed estimate.

The forms for the columns in this estimate of the removable steel type, cylindrical and without caps. These forms are rented from various concerns who make a business of furnishing and erecting them. The rental charge is at the current market price of $15.00 per column, including erection and removal.

The total cost, as will be noted from the detailed estimate of Type "E" for the panel, is $3,249.66, or a cubic foot cost of 9.8c and a square foot cost of $1.16.

TYPE "F":

Type "F" has the same general requirements as Type "E" and is of reinforced concrete design, beam and girder type, with the same column spacing and the same load.



DESCRIPTION	QUANTITY	UNIT COST	COST
FLOOR			
1 : 2 : 4 CONCRETE - SLABS & GIRDERS	2023 CU FT	$ .44	$ 890.12
FORMS (SLABS)	2800 SQ FT	.29	812.00
FORMS (GIRDERS)	933 SQ FT	.37	345.21
REINFORCING STEEL	11297 LBS	.049	553.55
COLUMNS			
1 : 2 : 4 CONCRETE	214 CU FT	.44	94.16
FORMS	7 PCS	15.00	105.00
REINFORCING STEEL	5176 LBS	.049	253.62
CEMENT FINISH	2800 SQ FT	.07	196.00

TOTAL COST = $3249.66

33,000 CU FT @ $.098
2800 SQ FT @ $1.16

The slab forms are priced at an increase over Type "E" on account of the "cut-up" nature of the work, the unit cost per square foot of panel being considerably more than the plain flat slab.

The concrete reinforcing, rental of column forms and floor finish are priced at the same unit price.

It will be noted from the detailed estimate that the total cost of the panel of Type "F" is $3,249.57. This gives a cubic foot cost of 9.7c and a square foot cost of $1.16.

NOTE:

There is a coincidence here in that the costs of Type "E" and Type "F" are the same, proving that in the designs submitted there is no particular advantage in so far as cost is concerned in favor either of Type "E" or "F".

TYPE "G":

Type "G" is a flat slab design, 2-way reinforcing, consisting of reinforced concrete flat slab, round columns, with flared heads and drop-head panels.

The flat slab forms, on account of the additional weight of the concrete, are figured at a slight increase over either Type "E" or "F".

The drop-heads are figured at an additional price of $10.00 each, over and above the flat slab area.

The column forms are figured at a slight increase to allow for the extra rental of the flared heads. This unit price of $16.00 each represents the current price charged for work of this character.

The concrete, reinforcing steel and cement finish are figured at the same unit prices.

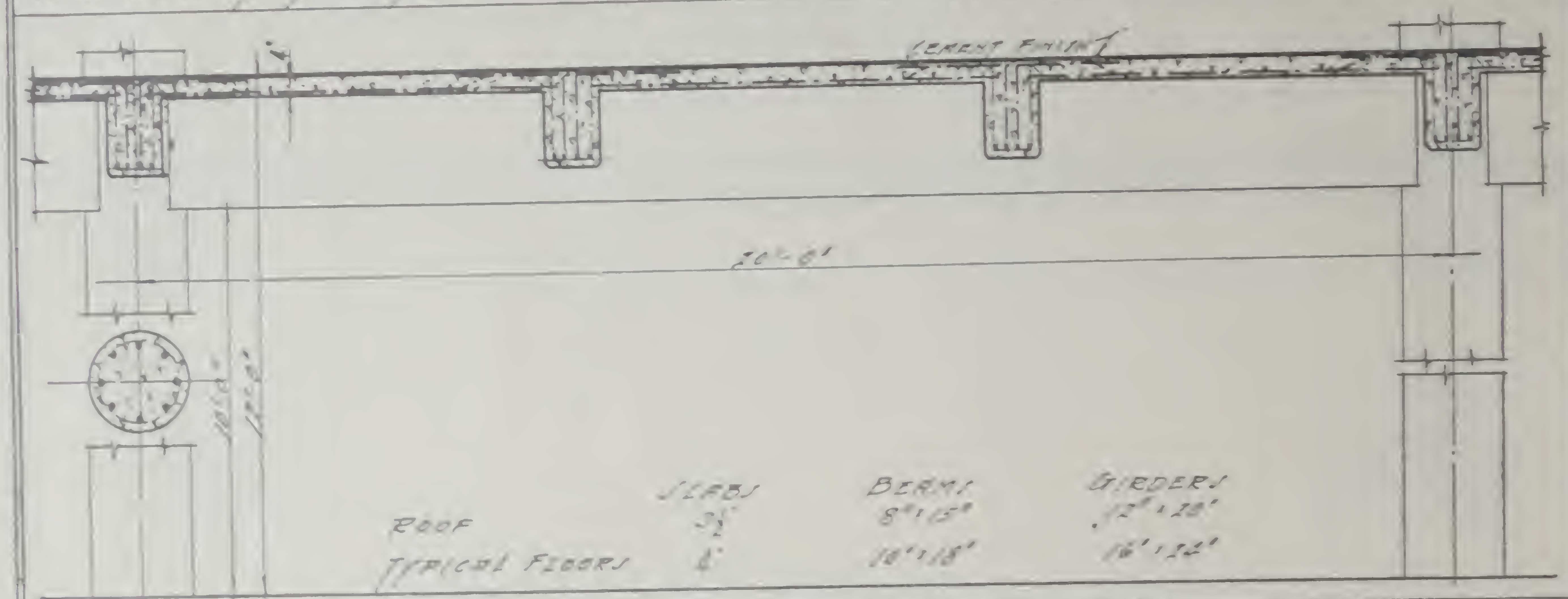
The total cost of the panel is $2,708.96, or a unit price of 8.8c per cubic foot of building and a square foot price of 97c.

CONCLUSION:

Type "G" seems to have a slight advantage in so far as cost is concerned over Types "E" and "F", the reason being that there is less steel per square foot of floor, less forms, contact area, per square

◦ TYPE F · BEAM & GIRDER ◦

PANELS 20'-0" x 20'-0" 10'-0" CLEAR STORY HEIGHT	LIGHT MANUFACTURING BLDG 6 STORIES & BASEMENT	100# L.L



DESCRIPTION	QUANTITY	UNIT COST	COST
FLOOR			
1:2:4 CONCRETE – SLABS, BEAMS & GIRDERS	1,502 CU. FT.	$ .44	$ 660.88
FORMS (SLABS)	2800 SQ. FT.	.31	868.00
FORMS (BEAMS & GIRDERS)	1977 SQ. FT.	.37	731.49
REINFORCING STEEL	8423 LBS.	.049	412.73
COLUMNS			
1:2:4 CONCRETE	223 CU. FT.	.44	98.12
FORMS	7 PCS.	15.00	105.00
REINFORCING STEEL	3547 LBS.	.05	177.35
CEMENT FINISH	2800 SQ. FT.	.07	196.00

TOTAL COST = $3,249.57

33,467 CU. FT. @ $.097
2,800 SQ. FT. @ $1.16

◦ TYPE G · 2 WAY FLAT SLAB ◦

PANELS 20'-0" x 20'-0" 10'-0" CLEAR STORY HEIGHT	LIGHT MANUFACTURING BLDG 6 STORIES & BASEMENT	100# L.L

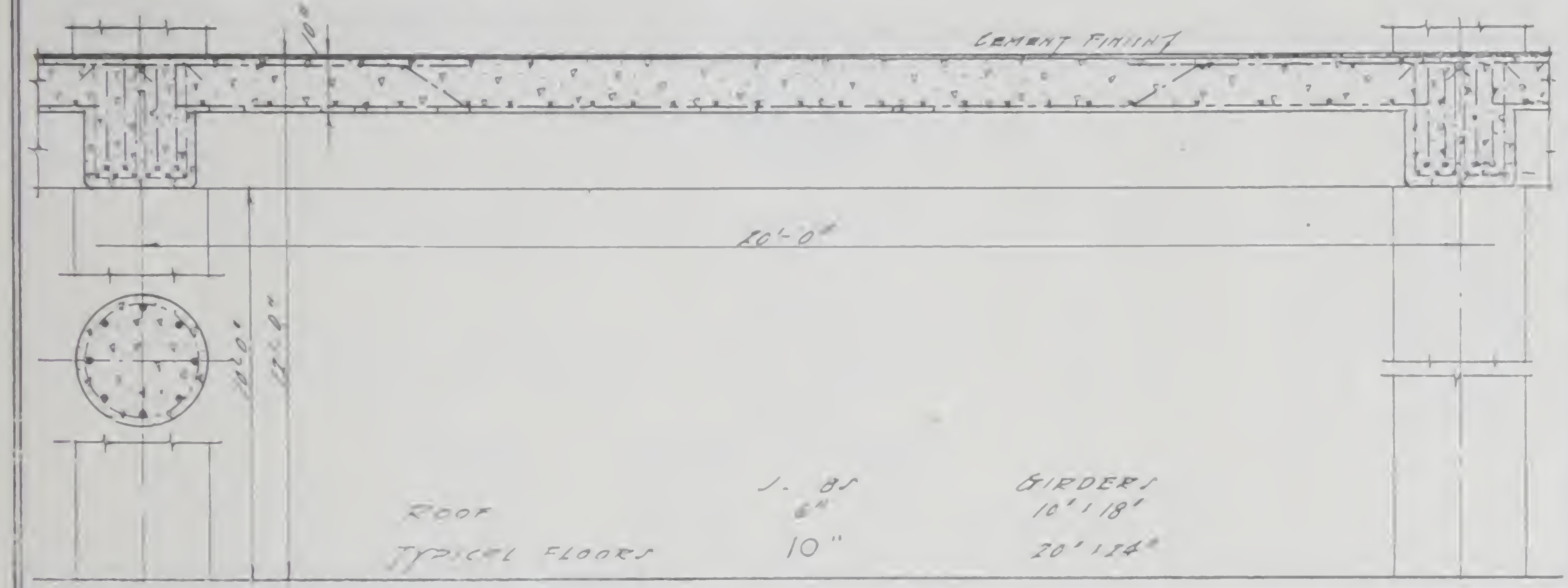
DESCRIPTION	QUANTITY	UNIT COST	COST
FLOOR			
1:2:4 CONCRETE – SLABS & DROP PANELS	1,800 CU. FT.	$ .44	$ 792.00
FORMS (SLAB)	2,800 SQ. FT.	.34	952.00
FORMS (DROP HEADS)	7 PCS.	10.00	70.00
REINFORCING STEEL	5,763 LBS.	.049	282.39
COLUMNS			
1:2:4 CONCRETE	203 CU. FT.	.44	89.32
FORMS	7 PCS.	16.00	112.00
REINFORCING STEEL	4305 LBS.	.05	215.25
CEMENT FINISH	2,800 SQ. FT.	.07	196.00

TOTAL COST = $2,708.96

30,557 CU. FT. @ $.088
2,800 SQ. FT. @ $.97

• TYPE H • 2 WAY SLAB & GIRDERS •

PANELS 20'-0" x 20'-0" 10'-0" CLEAR STORY HEIGHT | WAREHOUSE 8 STORIES & BASEMENT | 250# L.L.



DESCRIPTION	QUANTITY	UNIT COST	COST
FLOOR			
1:2:4 CONCRETE – SLABS & GIRDERS	3,521 CU FT	$ .44	$1,549 24
FORMS (SLABS)	3,600 SQ FT	.29	1,044 00
FORMS (GIRDERS)	1393 SQ FT	.37	515 .41
REINFORCING STEEL	20,135 LBS	.048	966 48
COLUMNS			
1:2:4 CONCRETE	543 CU FT	.44	238 92
FORMS	9 PCS	15.00	135 00
REINFORCING	12,834 LBS	.049	628 87
CEMENT FINISH	3,600 SQ FT	.07	252 00

TOTAL COST = $5,329.92

43,000 CU FT. @ $.124
3,600 SQ FT @ $1.48

foot of floor, less concrete in one instance and in general the forms are of simpler construction.

Warehouse Type

Types "H", "I", and "J" are reinforced concrete designs for a warehouse eight stories and basement, live load 250 lb. per square foot, panels and column centers 20 ft. x 20 ft., story height 10 ft. in the clear.

These designs were prepared by John W. Musham, M. W. S. E., of the Condron Co.

TYPE "H":

Type "H" is similar to Type "E", consisting of a two-way slab and girder construction, story height 12 ft.

The concrete quantities for all of these types were figured at the same unit prices as for the six-story building for comparative purposes, disregarding the savings which might be effected due to the fact that there is a greater volume of concrete and should, therefore, represent a corresponding decrease in the unit price.

It was estimated that 2½ floors of forms would be required, giving a re-use of forms of 4 times. Taking into consideration the greater re-use of forms, it was estimated that this would about offset the heavier framing required on account of the heavier construction and the same unit prices were used for these reasons and for better comparison with the cost of Type "E".

It will be noted from the detailed estimate that the total cost of Type "H" for the panel amounted to $5,329.92, or a cubic foot cost of 12.4c and a square foot cost of $1.48.

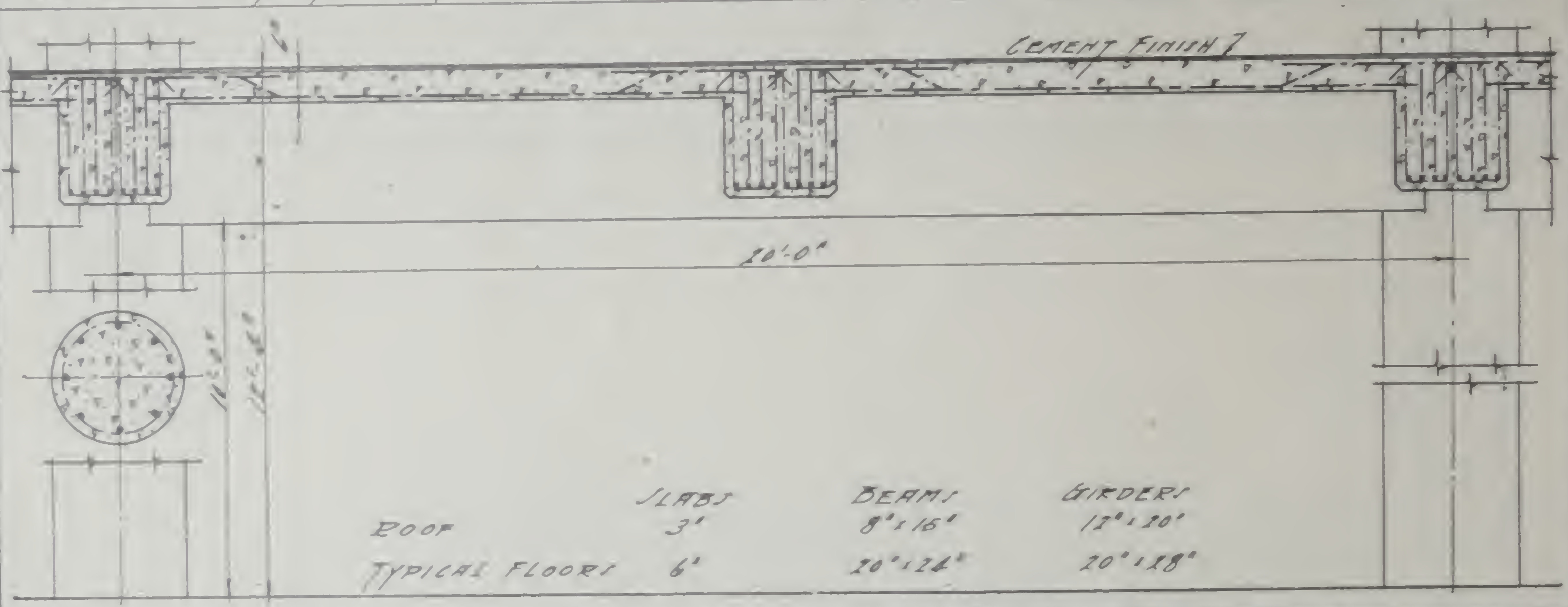
TYPE "I":

Type "I" is an eight-story warehouse and basement, same requirements as Type "H", of beam and girder concrete construction.

The forms, for the reasons as stated before in the foregoing analysis of the cost of Type "H", were figured at the same unit price as was estimated for Type "F".

TYPE I · BEAM & GIRDERS

PANELS 20'-0" x 20'-0" 10'-0" CLEAR STORY HEIGHT	WAREHOUSE 8 STORIES & BASEMENT	250# L.L



DESCRIPTION	QUANTITY	UNIT COST	COST
FLOOR			
1 : 2 : 4 CONCRETE — SLABS, BEAMS & GIRDERS	3,045 CU FT	$ .44	$ 1,339 80
FORMS (SLABS)	3,600 SQ FT	.31	1,116 00
FORMS (BEAMS & GIRDERS)	2,530 SQ FT	.37	936 10
REINFORCING STEEL	20,319 LBS	048	975 .32
COLUMNS			
1 : 2 : 4 CONCRETE	575 CU FT	44	253 00
FORMS	9 PCS	15 00	135 00
REINFORCING STEEL	10,980 LBS	049	538.02
CEMENT FINISH	3,600 SQ FT	07	252.00
		TOTAL COST =	$ 5,545 24

44,134 CU. FT @ $ .126
3,600 SQ. FT @ $1.54

The balance of the unit prices, as noted from the detailed estimate, are practically the same.

The total cost of the panel was estimated at $5,545.24. This gives a cubic foot price of 12.6c or a square foot price of $1.54.

Attention is here called to the fact that there is only a very slight difference in cost between Type "H" and Type "I".

TYPE "J":

Type "J" is eight-story and basement reinforced concrete warehouse, flat slab construction, two-way reinforcing.

For the reasons explained, the forms are figured at the same unit price as Type "G" and the balance of the unit prices are practically the same as for Types "H" and "I", allowing only for the slight extra cost of the reinforcing steel in the columns.

The total cost of this panel is $4,054.13, or a cubic foot cost of 10.2c and a square foot cost of $1.13.

CONCLUSION:

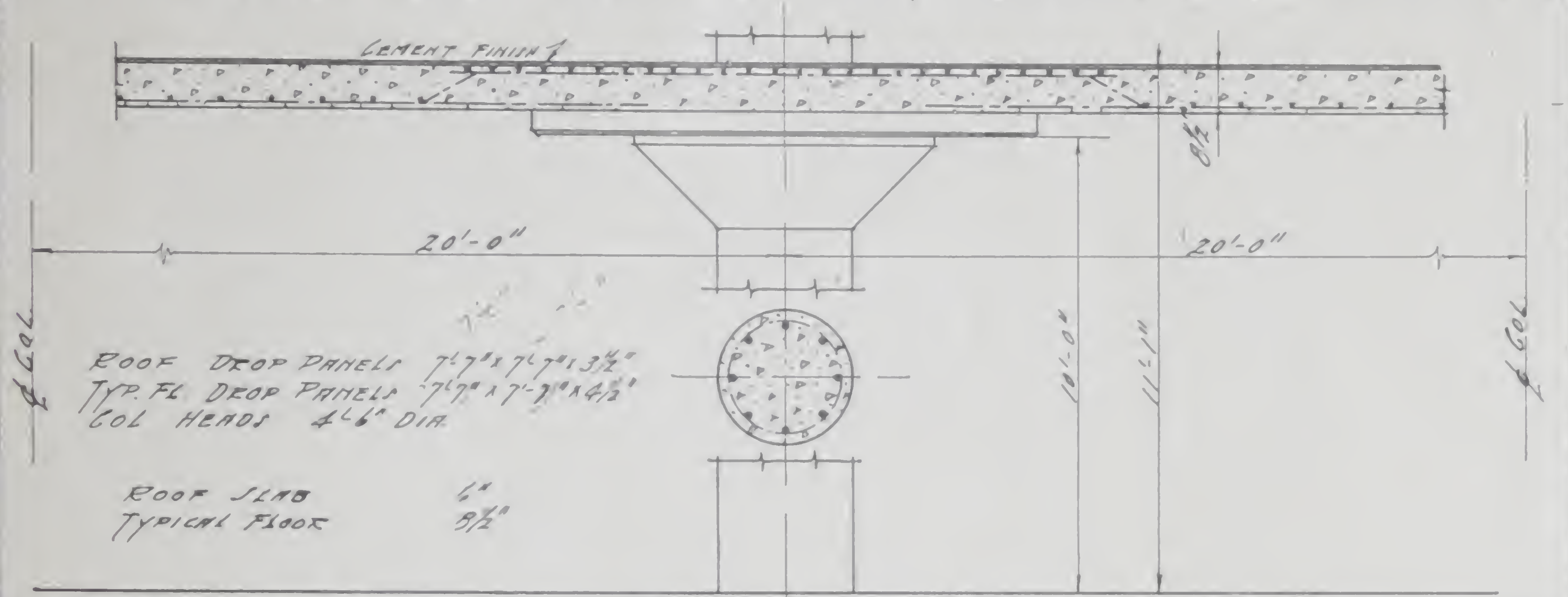
From a standpoint of cost only, there is no question that Type "J" is more economical than Type "H" and Type "I" for this particular load and span, the reason being that there is less reinforcing steel per square foot of floor, less forms (contact area) per square foot of floor and the form work is of simpler construction.

The particular design submitted by the engineers is very economical in that it permits the use of the same drop-head forms throughout the entire building, the story heights being the same permits the use of the same length of upright supports for forms without the necessity of cutting or splicing.

I wish again and particularly to emphasize here that it is quite possible with different spans and different loads to derive a different result, especially in the cases where the relative costs so closely approximate each other. There are other items in addition to the structural concrete design which might make the selection of one type of greater advantage than another in the case where a different

◦ TYPE J · 2 WAY FLAT SLAB ◦

PANELS 20'-0" x 20'-0" 10'-0" CLEAR STORY HEIGHT	WAREHOUSE 8 STORIES & BASEMENT	250# L L



DESCRIPTION	QUANTITY	UNIT COST	COST
FLOOR			
1 : 2 : 4 CONCRETE — SLABS & DROP PANELS	2,628 CU FT	$ .44	$1,156.32
FORMS (SLAB)	3,600 SQ FT	.34	1,224 00
FORMS (DROP HEADS)	9 PCS	10.00	90 00
REINFORCING STEEL	10,849 LBS	.048	520 75
COLUMNS			
1 : 2 : 4 CONCRETE	494 CU FT	.44	217.36
FORMS	9 PCS	16.00	144.00
REINFORCING STEEL	8,994 LBS.	.05	449 70
CEMENT FINISH	3,600 SQ FT	07	252 00
		TOTAL COST	$4,054.13

39,784 CU FT @ $.102
3,600 SQ FT @ $1.13

type of floor finish is used, such as wood floors with sleepers and fill.

The advantage of the suspended ceiling and the accommodation of sprinkler pipes and other mechanical piping, also must be taken into consideration in the selection of the type of design. These items are individual and it is not possible to make any particular recommendation, but in passing I simply call attention to the fact that they are factors which must be taken into consideration in arriving at a proper and most economical design. The results obtained in these various tables apply only to these individual designs and might easily be changed under different labor conditions and unquestionably would be considerably modified by different market conditions.

In selecting a design, the best method of determining the most economical is for the engineer to take test cases of a typical floor panel and to estimate per square foot the amount of concrete, reinforcing, etc., involved. A very good plan is to divide the cubic feet of concrete, including the concrete in the beams and girders, by the square feet of the panel, and in this way arrive at the board feet of concrete. The term "board feet" is somewhat of a misnomer, but refers to a piece of concrete 12 in. x 12 in. x 1 in. thick, similar to the term applied to board feet of lumber. In reducing the concrete to the number of board feet of concrete per square foot, the comparative quantities in the different designs can be determined at a glance.

The projected area of the forms, or what is sometimes termed the contact area, should be carried out in square feet, including the forms for beams and girders, and the total number of square feet divided by the square feet of the panel to determine the amount of form area per square foot of floor. The total weight of the reinforcing steel should be divided by the square feet of the panels in order to give the weight per square foot. Allowance should be made for the floor

finish and plastering, if any, per square foot of panel area. The columns should be figured separately, including concrete, forms, reinforcing, etc., and the total cost of quantities divided by the square feet of panel area. A very quick approximate method is to take the average sized column of one floor. Having arrived at all of the quantities in a typical panel the comparative price per panel or per square foot can be readily determined. This is the quickest test for a comparison of different designs and one that cannot be disputed even though there might be a difference of opinion with reference to the unit prices.

If it is desired to use any of the square foot prices given in this paper for approximate figures, rather than for comparative figures, attention is called to the fact that it is necessary to add for the filling in spandrels at one end and one side of the building and also for the filling in columns. These quantities vary according to the size of the building and the shape. For example, a building 50 ft. x 100 ft., 3 spans wide and 6 spans long would contain 18 panels per floor. The excess, filling in columns, amounts to 10 and the unit price per square foot would be increased by 44% of the cost of the columns. For a building 100 ft. x 100 ft., assuming a total of 36 panels, the excess, filling in columns, amounts to 13, or an increase in the square foot price on account of excess filling in columns of 36% of the cost of the columns. The filling in beams and girders would vary according to the direction of the framing. In the case of a building 50 ft. x 100 ft., an allowance must be made for 150 ft. of excess filling in beams and girders, and in the case of a building 100 ft. x 100 ft., an allowance must be made for 200 lineal feet of excess filling in beams and girders.

Assuming that in the case of a building 50 ft. x 100 ft., the beams extend across the 50 ft. width of the building, the increase in the beams would be 5.5% and the increase in the girders 33⅓%. In the case of a building 100 ft. x 100 ft., the increase in the filling in beams would amount to 5.5%, and for the girders 16⅔%.

For rough approximate figures if the above unit prices are increased by approximately 25% it will take care of the extra filling in columns, beams and girders and extra cost of the spandrels in the average job.

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